QUALITY ASSURANCE SIEVE TEST STUDY

INTRODUCTION

In May, 1980 the engineering department was asked to study the Quality Assurance sieve test. This test is run on every tobacco product that Philip Morris produces and is used to evaluate processing functions. The test involves running a sample through a series of four rectangular screens wth progressively smaller holes. The sample is broken up into fractions named in order of decreasing size: longs, mediums, shorts, smalls, and fines. Q.A. has problems with the sieves varying from set to set both in wire mesh specifications and in screen area. The difference in screens can give as much as 6% or more difference in some fractions from set to set. Tests have been done under the supervision of Al Calkins from Q.A. to study the differences between six sets of rectangular screens. Results appear in Appendix I. The differences between these screens were relatively small according to information received from other people who had used rectangular screens. Since all the screens tested were new, they may be more uniform than used screens. A memo dated October 4, 1979 from M.J. Abel of R&D to K.S. Burns described a test comparing R&D shakers and sieves to Q.A. shakers and sieves. Results appear in Table 1.

Q.A. Screens	% Longs	% Mediums	% Shorts	% Smalls	% Fines
R&D Shaker	22.1 ± 0.3	55.0 ± 0.4	19.3 ± 0.3	2.7 ± 0.2	0.9 ± 0.1
Q.A. Shaker	22.6 ± 0.4	55.6 ± 0.4	18.5 ± 0.4	2.5 ± 0.1	0.8 ± 0.1
R&D Screens					
R&D Shaker	20.4 ± 0.7	60.6 ± 2.0	15.0 ± 1.6	2.7 ± 0.2	1.3 ± 0.3
Q.A. Shaker	20.5 ± 0.8	61.9 ± 0.6	14.1 ± 0.3	2.8 ± 0.1	0.8 ± 0.0

TABLE 1. - R&D VS. Q.A.

Very little difference was noted between shakers, but a difference of as much as 6.3% (mediums) was noted between screen sets. Tests supervised by Henry Kelly and Bob Jensen of Q.A. were performed with a new type of round stainless steel sieve bought from Tyler Industrial Products. The round sieves used tightly stretched, closely toleranced wire mesh instead of loose industrial grade mesh used in the rectangular sieves. The results, which appear in reduced form in Appendix II, indicated that the round screens produced more repeatable results from set to set.

Engineering bought two sets of seive screens from Newark Wire Cloth Co. similar to the screens from Tyler Industrial Products. The sieves are all stainless steel, twelve inch diameter round pans with stainless steel bottom pans. The wire mesh used is U.S.A. Standard testing grade (ASTM E-11-70) stainless steel wire cloth. Seven different meshes were bought for each set including U.S.A. Standard numbers 6, 12, 18, 20, 35, 45, and 50. The specifications for these mesh numbers appear in Table 2.

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U.S. Standard No	Wire Dia. (In.)	Sieve Opening (In.)	% Open Area	Holes/In.
6	.0484	.1320	53.5	5.5
12	.0319	.0661	45.5	10.2
18	.0228	.0394	40.1	16.1
20	.0201	.0331	38.7	18.8
35	.0134	.0197	35.4	30.2
45	.0097	.0139	34.7	42.3
50	.0085	.0117	33.5	49.5

TABLE 2. - MESH SPECIFICATIONS

The sieves were used on a standard Q.A. lab shaker modified to accept the round pans. The shaker ran at 350 rpm with a stroke of 3/4". The standard Q.A. sieve test procedure was followed. That procedure began by collecting samples in plastic boxes. The boxes were sealed and the samples were allowed to sit overnight. The sample was placed on the top screen of the sieve set and the timer was set for five minutes which automatically started the shaker. After five minutes the shaker turned off automatically and the screens were removed from the shaker. The technician, using a heavy cloth glove, emptied the sieves one by one into 24" x 24" sheets of folded heavy brown paper. The samples were then emptied into a plastic box and weighed on a Mettler balance. After being weighed, the fractions are either recombined or discarded, depending on the test.

PROCEDURE

The first series of tests run were moisture tests. These tests were run to determine the effect of sieving on the amount of moisture in a sample. Since later tests would involve two successive sievings, a large change in moisture could bias results. All moisture tests used 150 grams of Marlboro King Size cut filler taken from the final weigh belt. The standard sieve procedure was followed and fractions were recombined into a plastic bag. The bag was shaken to mix the sample and about five grams was removed and put into a cup for the O.V. test. The cup was weighed and put into an oven. After three hours the cup was removed and weighed. The difference in weight is assumed to be all the sample's moisture and is designated as percent O.V. The O.V. test was run for nine different mesh combinations after both one and two sievings.

The second set of tests were called degradation tests. These tests involved running the same sample through the sieves twice, weighing fractions after each sieving. This test determines how much

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Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

attrition is caused by the sieving alone. Data from the moisture test could be applied to the degradation test since some of the moisture test samples were sieved twice. Degradation tests were run for 50, 100, 150, and 200 gram samples in combination with DIET - exit silo, Marlboro King Size cut filler-final weigh belt (MKS-FB), and Marlboro King Size cut filler-exit silo (MKS-ES).

The third set of tests was called the comparison test. This test involved sieving a sample, weighing it, and sieving again in the second set of screens. The results of this test, compared with the results of the degradation test, can show differences in screens from set to set. The comparison test was run for three different mesh combinations with 150 gram samples of MKS-FB. Ripper shorts were also run through a comparison test.

Some special tests were also run to determine characteristics of the tobacco in the sieves under unusual conditions. Results of these tests will appear in a later section.

RESULTS AND DISCUSSION

Moisture Test

Results of the moisture test appear in Table 3. These are averages over ten to fifteen samples. O.V. tests were also done for samples without any sieving. The average percent moisture of samples taken immediately was 13.61%. The average percent moisture of samples after 24 hours residence time was 13.54%.

	O.V. (%)				
Mesh Combination	One Sieving	S.D.	Two Sievings	S.D.	Change in % O.V
12, 18, 20, 45	13.21	0.13	13.13	0.19	- .08
6, 18, 20, 45	13.38	0.19	13.23	0.19	- .15
6, 12, 18, 20, 45	13.47	0.13	13.16	0.16	- .31
6, 12, 18, 35, 50	13.45	0.08	13.26	0.13	- .19
6, 12, 20, 35	13.66	0.14	13.41	0.09	- .25
6, 12, 20, 45	13.51	0.51	13.67	0.15	+ .16
12, 20, 35, 50	13.96	0.65	13.34	0.15	- .62
6, 12, 18, 20, 35	13.13	0.14	13.51	0.14	+ .38
6, 12, 18, 35	13.60	0.11	13.46	0.12	- .14
Average	13.49		13.35		- .14

TABLE 3 - MOISTURE TEST RESULTS

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Average standard deviation for the O.V. figures was 0.17. There is no noticable trend in moisture change according to mesh combination. So, the change in moisture is probably not affected by the mesh combination used. Also, the degree of attrition of the sample does not seem to be affected by the amount of moisture change. Data from these tests appears in Appendix III. Graphs showing attrition of the samples appear in Appendix IV.

Mesh Combinations

The reason for buying seven different meshes was to see if an optimum combination could be found. The nine mesh combinations which were tested appear in Table 4.

6, 12, 18, 35
6, 12, 20, 35
6, 12, 20, 45
6, 18, 20, 45
6, 12, 18, 20, 35
6, 12, 18, 20, 45
6, 12, 18, 35, 50

TABLE 4 - MESH COMBINATIONS

An overview of the fraction distributions for each mesh combination appears in Figures 1 and 2. The objective when evaluating the usefulness of a mesh combination was to find one that would break up the sample as evenly as possible. If possible, there should be no more than 40% of the sample remaining on any screen. This guideline insures that a screen does not get overcrowded and impede the sifting of smaller particles. Visual checks of the fractions on the screens were helpful in evaluating the mesh combination. A check of the fractions showed that the sample need not be broken up further than the #35 screen. The present rectangular screens break up the sample into two fractions after passing the 30 mesh screen. The result is to separate large dust from small dust. Neither of the fractions are useful in the manufacture of cigarettes so they can be combined to represent unsatisfactory product. Also, to break up the sample into smaller groups, the top pan must be more coarse than the 10 mesh presently used. Therefore, the #6 screen must be used. So, the top pan must be the #6 and the bottom pan must be the #35. Possible combinations with those pans are #6, 12, 18, 35; #6, 12, 20, 35; and #6, 18, 20, 35. The #6, 18, 20, 45 combination left 60% of the sample on the #10 screen and was, therefore not acceptable. Further testing was continued with the remaining two conditions.

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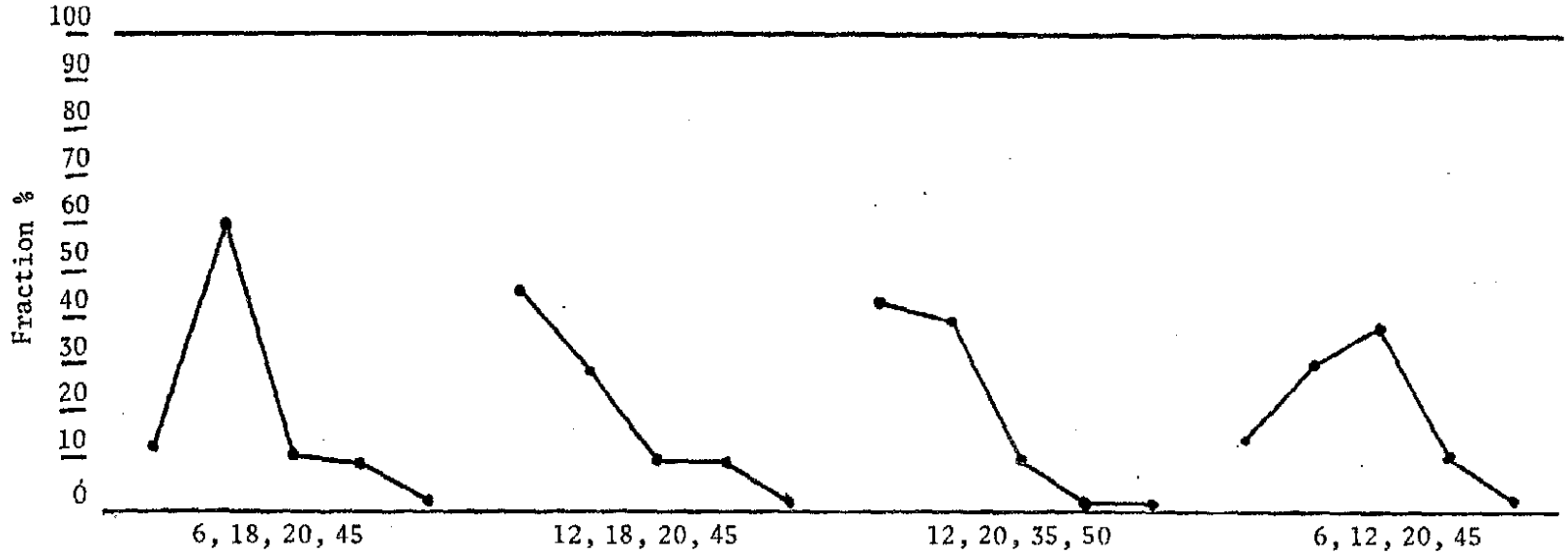
Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001



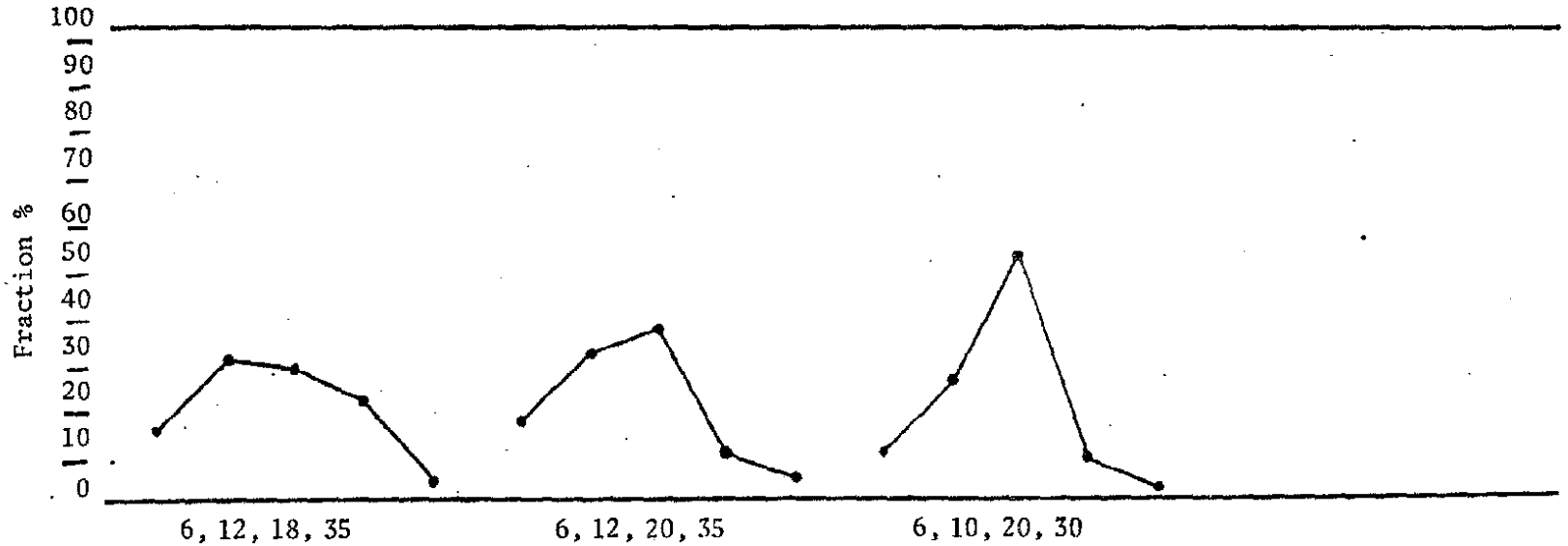


FIGURE 1 - FRACTION DISTRIBUTION (4 SCREENS)

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Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

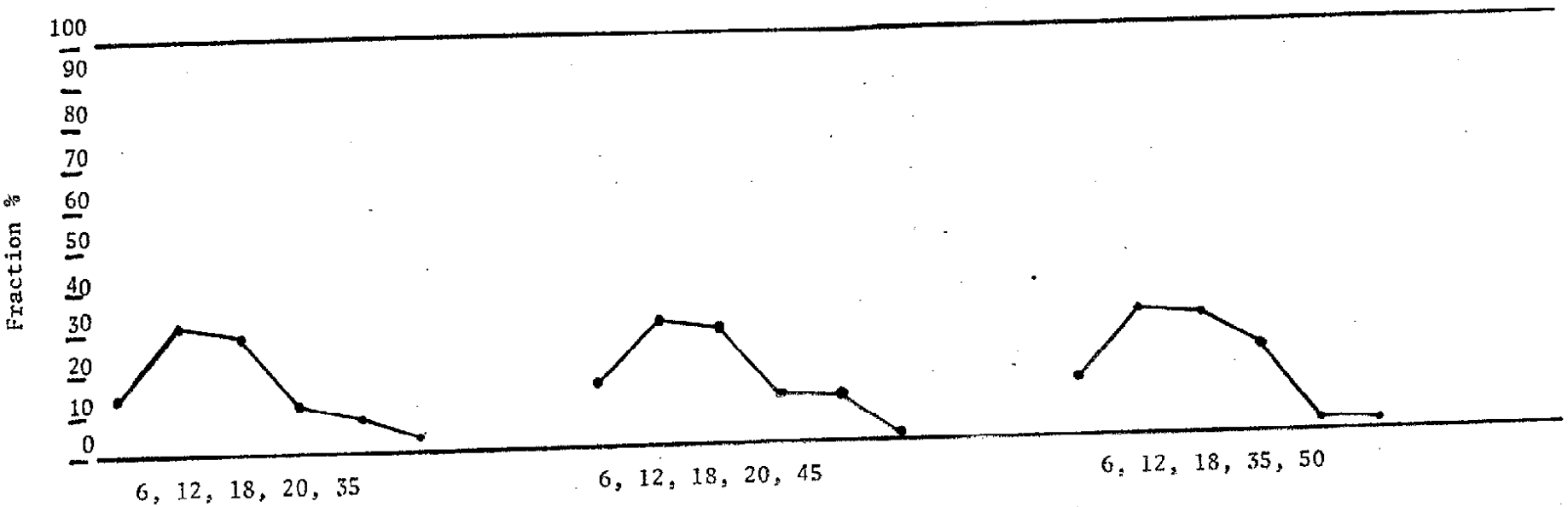

FIGURE 2 - FRACTION DISTRIBUTION (5 SCREENS)

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Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

Degradation Test

Analysis of the data from the degradation test was done for all nine combinations. Graphs were made for each combination to study the effect of two successive sievings. Some generalizations can be made about this effect:

1. There are always fewer longs in the second sieving than in the first sieving.

2. The amount of tobacco lost between sievings ranges between 0.35 to 0.60 grams regardless of mesh combination, sample size, or product.

3. The fines fraction stays about the same from first sieving to second.

4. For cut filler at 150g the loss of longs from first to second sieving is split up evenly to produce a rise in mediums, smalls, and shorts.

5. The change in fractions from first to second sieving was much smaller for DIET. Also, on the second sieving DIET lost longs, mediums, and fines and gained in shorts and smalls.

6. Larger samples have a higher percentage of longs.

Data and graphs for degradation tests appear in Appendices V and VI. Graphs comparing sample size to fraction percent and product to fraction percent appear in Appendices VII and VIII respectively.

Comparison Test

Comparison tests were done for the following conditions:

#6, 12, 18, 35 /150g /MKS-FB (twice)
#6, 12, 20, 35 /150g /MKS-FB
#12, 18, 20, 45 /150g /MKS-FB
#6, 12, 18, 35 /100g /MKS-FB
#6, 12, 18, 35 /150g /Ripper shorts.

Data sheets and graphs for these tests appear in Appendices IX and X. Graphs show the #6, 12, 20, 35 mesh combination to be most repeatable. The other acceptable combination (#6, 12, 18, 35) shows large differences around the #18 screen from set #1 to set #2. The results of these comparison tests could mean three things. First, the #18 screens are at far enough ends of the tolerance that the sieve results are significantly affected by the variation. Second, wear including wire slack, surface polishing or small dents affected

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the screens enough to change results. However, since degradation tests run 1-1/2 months apart show no significant difference, these wear conditions are probably not important. Third, the #12 and #18 screens are so close to the same size mesh that a small difference in screens can produce a large difference in test results. The #12 and #20 are further apart in size, making tolerances for wire diameter and hole size less critical. When short and small fractions for both comparison and degradation tests are combined, the results show less than 2.5% difference between sets for both the #6, 12, 18, 35 and #6, 12, 20, 35 combinations. But, when all fractions are evaluated separately, only the #6, 12, 20, 35 combination has less than 2.5% difference between sets. Data and Graphs on set differences appear in Appendices XI and XII.

Special Tests

Some special tests were run to observe the behavior of the sieving under certain unusual conditions. All tests were done with 150 grams of MKS-FB on screens #6, 12, 18, 35. The first test done was one to see how the longs are affected by further sieving. The sample was run through a regular sieving and all fractions were discarded except the longs. Then, the longs were replaced on the top screen and sieved for another 5 minutes. Results appear in Table 5.

% Longs	% Mediums	% Shorts	% Smalls	% Fines
50.66	36.38	10.54	2.33	0.10

TABLE 5 - LONGS TEST

In five minutes, half of the longs had gone through the #6 screen, There were long pieces of tobacco on each of the #12, 18 and 35 screens. These results show that given enough time, most of the sample could sift down out of the #6 screen. So, there is almost no way of determining an optimum shaking time other than to pick a time and standardize. The present shaking time of five minutes seems to be adequate for separating the tobacco sample.

The second special test was done to determine the amount of fines that are either produced by excessive sieving or retained in the first sieving. The sample was run through a regular sieving and all fractions were weighed. Then, the fines were discarded and the sample was recombined. After another five minutes sieving, the fractions were weighed again. Results appear in Table 6.

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Fraction weight (grams):	Longs	Mediums	Shorts	Smalls	Fines	Total
First sieving	20.82	45.62	43.36	32.38	6.40	148.58
Second sieving (Fines removed)	17.48	45.06	44.98	33.99	0.35	141.86

TABLE 6 - FINES TEST

An additional 0.24% of the original sample came out as fines during the second sieving. The average change in fines during the degration tests was +0.11%. Although the differences in fines of 0.13% is probably not significant, the results of the fines tests are interesting because they show that some fines in the sample are probably clinging to other fractions.

The decision to run the third special test was a result of screens tilting during some regular round sieve tests. For the special test the screens were tilted deliberately to see how the tilting in the regular tests had affected the results. A piece of carpet was folded and placed under one side of the bottom pan. Tests were run with carpet first under the front of the pan and then under the back of the pan. Fraction percentages appear in Table 7.

	% Longs	% Mediums	% Shorts	% Smalls	% Fines
Carpet at front of pan	12.78	30.30	29.37	22.87	4.68
Carpet at rear of pan	15.47	29.71	28.60	22.19	4.03
No tilt	15.63	30.56	28.70	21.05	4.07

TABLE 7 - SCREENS TILTED

The screens for this test were tilted much more than the tilt observed during regular testing. Judging from the special test results, although tilting lessens the total sieve area, it does not much affect the sieve fractions.

The fourth special test illustrated the effect of tobacco tangling on sieve results. The sample was pushed through a 1/2" screen (2 holes/in.) by hand and then sieved. The results of two successive sievings appear in Table 8.

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	% Longs	% Mediums	% Shorts	% Smalls	% Fines
Separated before sieving					
First sieving	6.08	32.31	31.59	24.98	5.05
Second sieving	4.55	31.56	32.01	26.75	5.13
Not sep. before sieving					
First sieving	15.06	29.55	28.80	22.49	4.10
Second sieving	13.35	28.95	29.36	24.07	4.27

TABLE 8 - TANGLING EFFECT

The difference in longs of about 9% can be attributed to clumping and tangling of the longer, moist pieces. The 1% difference in fines cannot be explained without further testing. The change in longs from first to second sieving is about the same for both the separated condition and the regular condition. The decrease in longs for the separated condition indicates once more that the sample might completely sift out of the #6 screen if given enough time.

The last special test was done to see how the #18 screen from set #2 would affect the results of the sieve test if put in place of the #18 screen in set #1. Since the fraction on the #18 screen was the major difference between sets, exchanging screens could show how different they are. Results from this test appear in Table 9.

	% Longs	% Mediums	% Shorts	% Smalls	% Fines
All Set #1					
First sieving	16.63	30.46	28.28	20.63	4.00
Second sieving	14.53	30.57	28.91	21.88	4.11
All Set #2					
First sieving	15.27	31.14	28.95	20.76	3.88
Second sieving	13.70	32.49	32.02	18.06	3.74
Set #1 - Change #18 screen between sievings					
First sieving	13.46	29.52	29.26	23.39	4.38
Second sieving	11.55	29.26	33.97	20.65	4.58

TABLE 9 - EXCHANGING #18 SCREEN

Graphs of these conditions appear in figures 3, 4, and 5. As the graphs show, the #18 mesh screens from set #1 and set #2 are significantly different.

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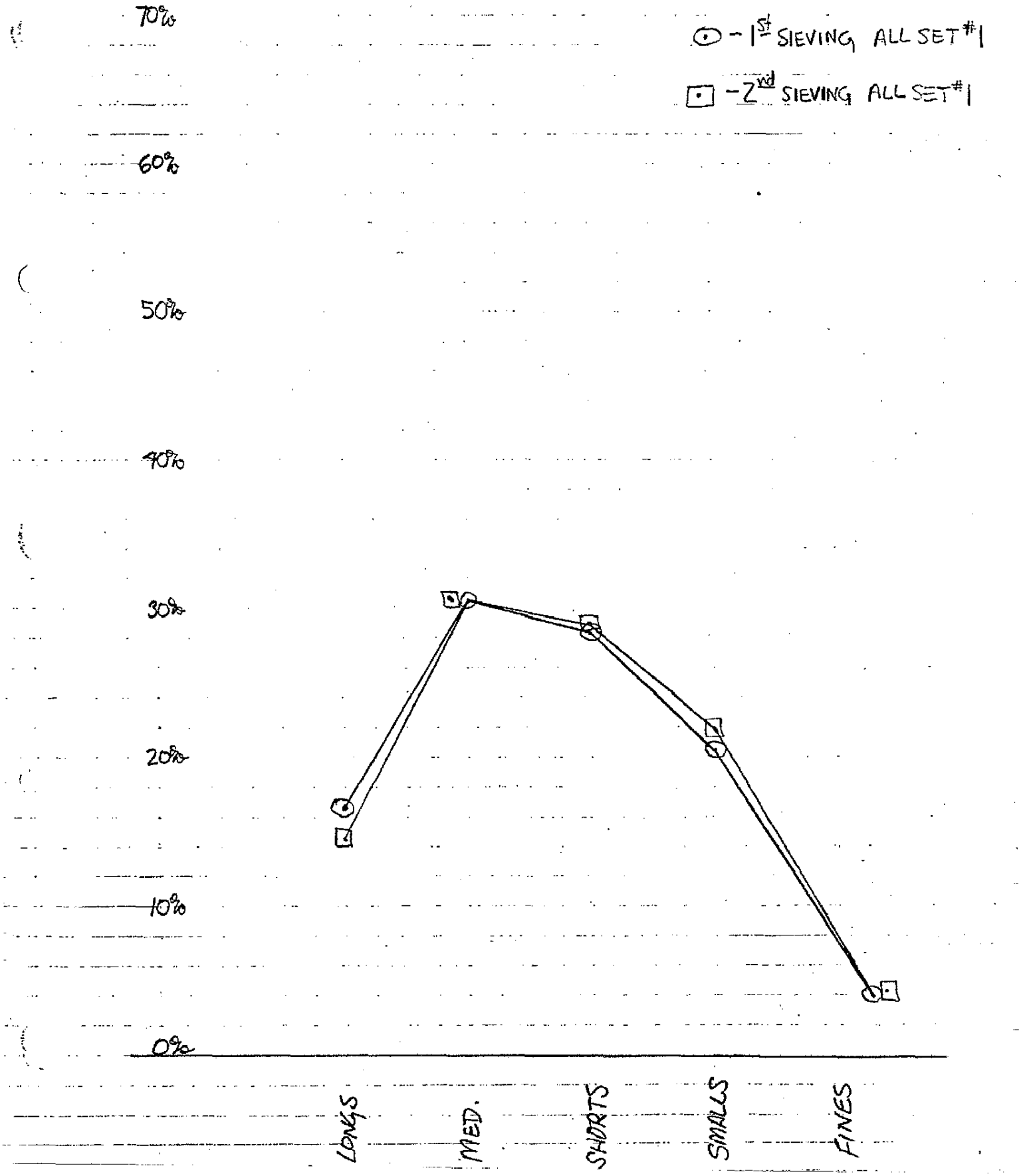
Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

FIGURE 3 - #18 SCREEN TEST
6, 12, 18, 35



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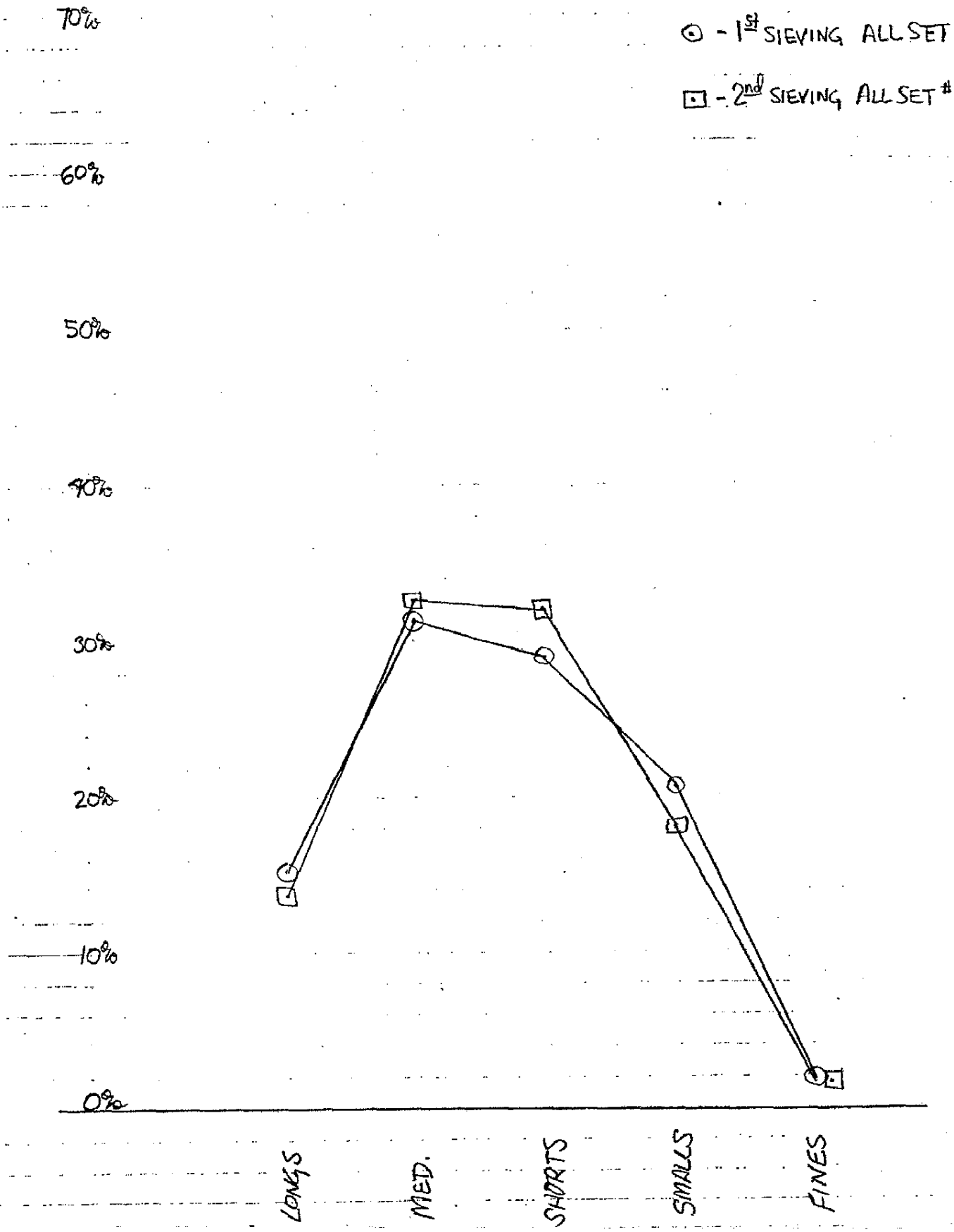
Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

FIGURE 4 - #18 SCREEN TEST
6, 12, 18, 35



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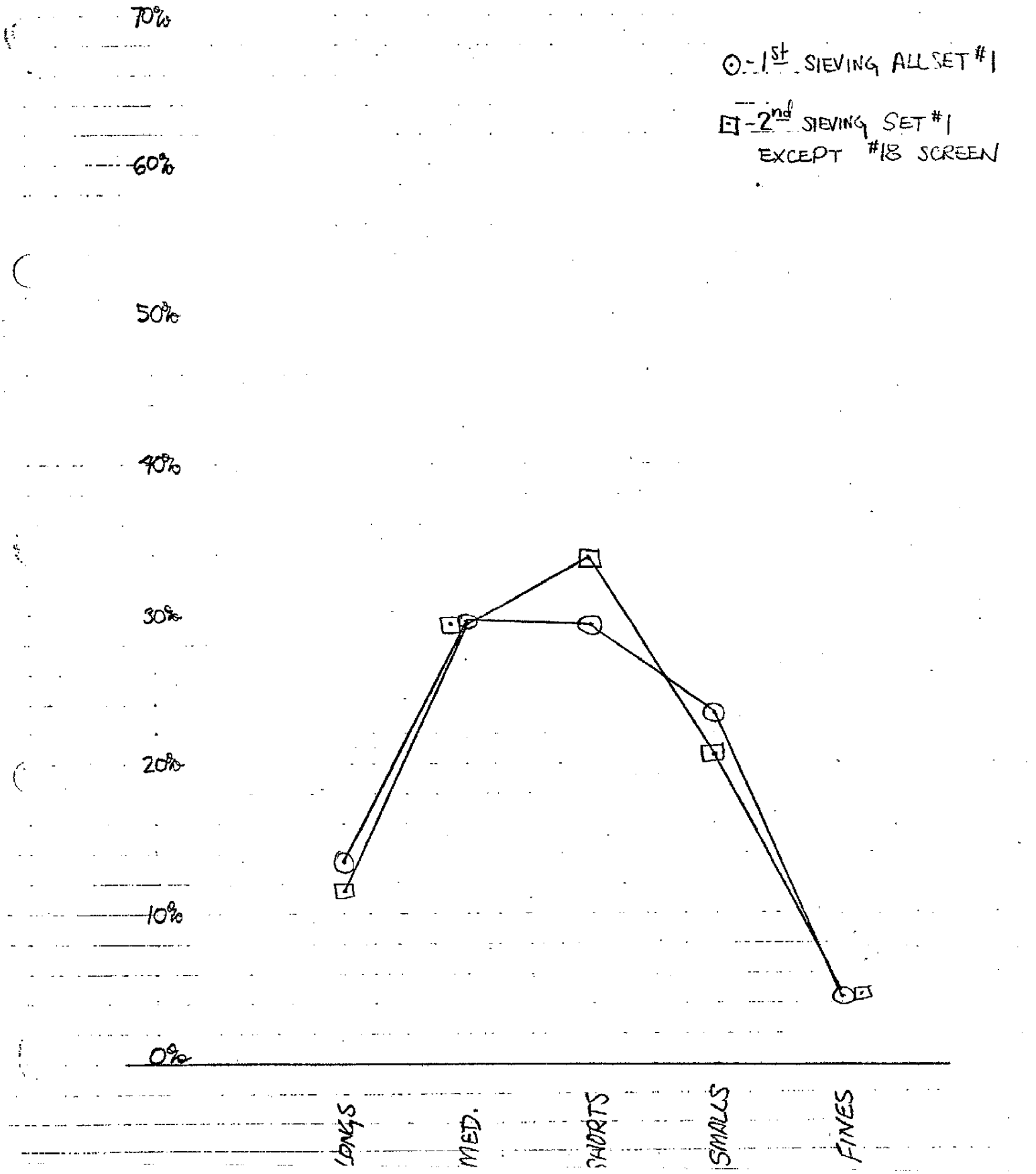
Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

FIGURE 5 - #18 SCREEN TEST
6, 12, 18, 35



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Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

CONCLUSIONS

Based on information gained in the round sieve screen testing and testing by A. Calkins, H. Kelly, and R. Jensen, the following conclusions can be made:

1. Testing grade wire mesh should be used. The tolerances are much closer than the presently used industrial grade screen and can only make the screens more repeatable. The two major testing grade wire meshes are U.S.A. Series and Tyler Series. Both of these series meet the specifications of the American Society for Testing Materials (ASTM) E-11-70. Only the U.S.A. Standard has been used for Philip Morris testing so far.

2. The wire mesh should be stretched as tightly as possible across the bottom of the pan to avoid screen sagging.

3. The sieves should be bought from a sieve screen manufacturer. The technology required to stretch the screens and secure them without damage is not available to local machine shops. Several companies make sieve screens similar to the type needed for the Philip Morris sieve test. Newark Wire Cloth Co. and Tyler Industrial Products have supplied sieves so far. A set of 12" diameter round stainless steel sieves including bottom pan and four screens would cost about $550 after Philip Morris modifications. The rectangular screens presently used cost about $500 per set from Bryce Jewett Machine Shop. As far as the quality of the equipment, the round screens are a much better value.

4. The five minute shaking time is adequate for separating samples of all products.

5. The 150 gram sample is a good size since it gets a large enough sample to be representative and does not seem to overload the longs screen.

6. The #6, 12, 20, 35 mesh combination is best based on testing so far, but more testing on this combination is advised.

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RECOMMENDATIONS

Recommendations for further action on the sieve test appear below.

1. Since no long term testing has taken place to determine the life and uniformity of screens over a long period of time, the ideal action would be to use round ASTM screens in one lab for a long period of time (6 mo. - 1 yr./three shifts) for observation. I would recommend testing a few more sets of #6, 12, 20, 35 screens before any standardization to check for uniformity. Due to the importance of the sieve test, there should be no doubt that the conditions chosen for the test are best.

2. Observations should be done to see if there is any noticeable difference in sieve results from one technician to another. While observing the sieve tests, I noticed that each technician performs the test slightly different. Additional standardization may be possible.

3. Changes to the sieve shaker to make the test more efficient may be possible. A different kind of movement other than straight-line back and forth may be better.

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APPENDIX I

Al Calkins - Screen Comparison Test

Shaker I

Set	% Longs	% Mediums	% Shorts	% Smalls	% Fines
A	20.43	56.55	19.99	2.36	.66
B	18.52	60.14	18.43	2.29	.62
C	17.66	59.53	19.17	2.78	.86
D	17.80	59.18	19.67	2.66	.68
E	18.58	58.15	19.90	1.57	1.79
F	17.77	59.29	19.82	2.51	.62
Avg.	18.46	58.80	19.50	2.03	0.87
S.D.	1.04	1.28	0.60	0.92	.46

Shaker II

A	20.10	56.95	20.05	2.32	.58
B	17.03	61.16	18.54	2.69	.58
C	17.00	60.03	19.44	2.38	1.16
D	18.97	58.50	19.42	2.52	.59
E	18.78	58.60	19.35	1.65	1.61
F	17.99	59.34	19.47	2.59	.60
Avg.	18.30	59.10	19.38	2.36	.85
S.D.	1.20	1.44	0.48	0.37	.44

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Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

APPENDIX II

R. H. Kelly - Round Screen Comparison
All Samples Sieved Only Once

Set	#8	#10	#20	#30	#50	Pan
DIET						
1	23.18	8.26	58.58	7.51	1.79	0.69
2	23.16	9.84	56.27	7.98	1.96	0.79
Ripper Shorts						
1	10.99	8.61	70.51	9.48	0.33	0.08
2	10.66	10.31	68.55	9.98	0.41	0.09
Marlboro Cut Filler						
1	34.94	9.13	43.92	7.62	2.67	1.72
2	34.31	10.17	42.80	8.06	2.79	1.88
DIET						
3	21.90	9.60	57.14	8.61	2.13	0.63
4	22.49	7.93	59.41	7.82	1.84	0.52

Samples Sieved for a Second Time on Set #2

DIET						
1	23.11	10.03	54.59	9.47	2.22	.57
2	22.79	8.60	56.71	12.40	2.15	.51

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Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

APPENDIX III

Mositure Test Data

Mesh Combination	No. of Sievings	Avg. % O.V.	S.D.
6, 12, 18, 35	1	13.60	0.11
	2	13.46	0.12
6, 12, 20, 35	1	13.66	0.14
	2	13.41	0.09
6, 12, 20, 45	1	13.51	0.51
	2	13.67	0.15
6, 18, 20, 45	1	13.38	0.19
	2	13.23	0.19
12, 18, 20, 45	1	13.21	0.13
	2	13.13	0.09
12, 20, 35, 50	1	13.96	0.56
	2	13.34	0.15
6, 12, 18, 20, 35	1	13.13	0.14
	2	13.51	0.14
6, 12, 18, 20, 45	1	13.47	0.13
	2	13.16	0.16
6, 12, 18, 35, 50	1	13.45	0.08
	2	13.26	0.13

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Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

APPENDIX IV

Mositure Test

Attrition Graphs

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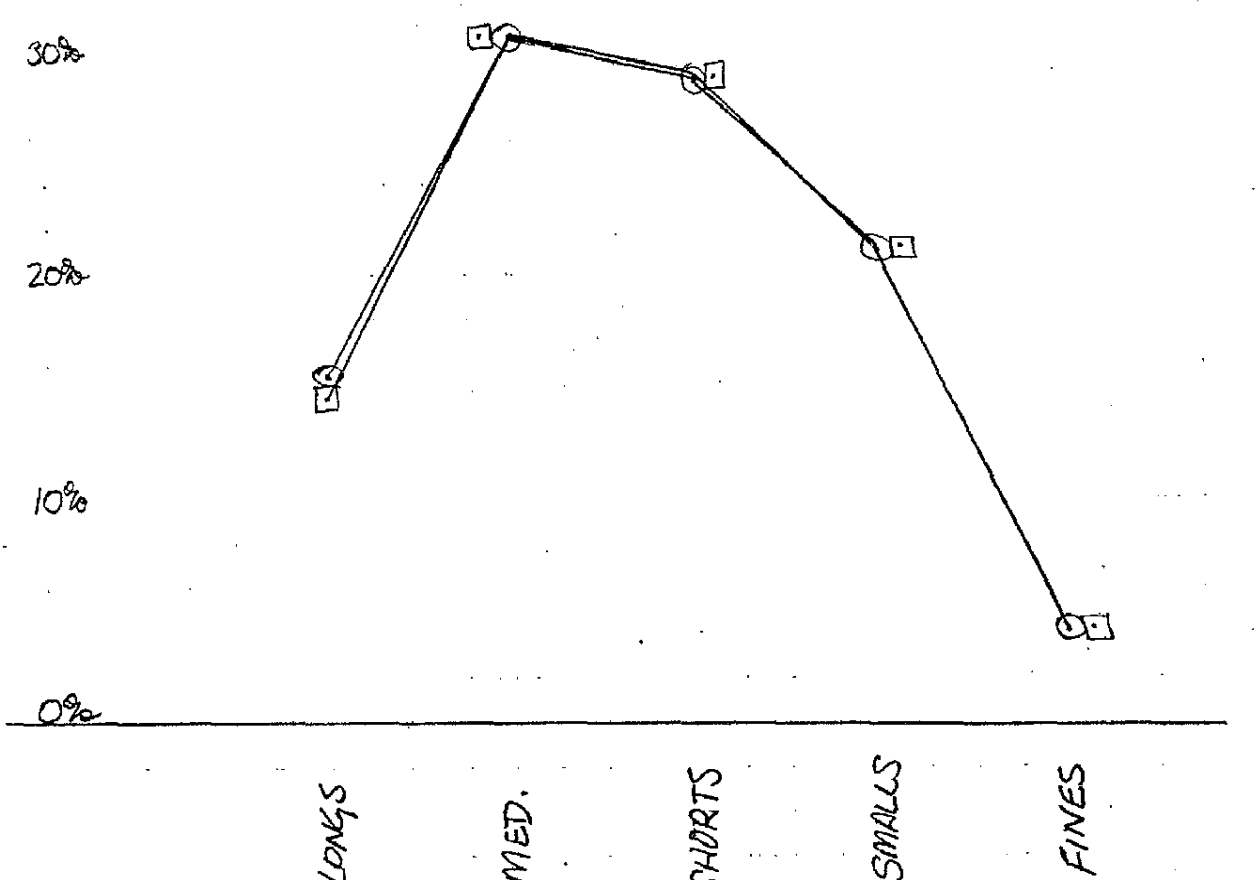
Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

6, 12, 18, 35 COMBINATION
CHANGE IN O.V. = -0.14%

⊙ - FIRST SIEVING
O.V. = 13.60

⊡ - SECOND SIEVING
O.V. = 13.46



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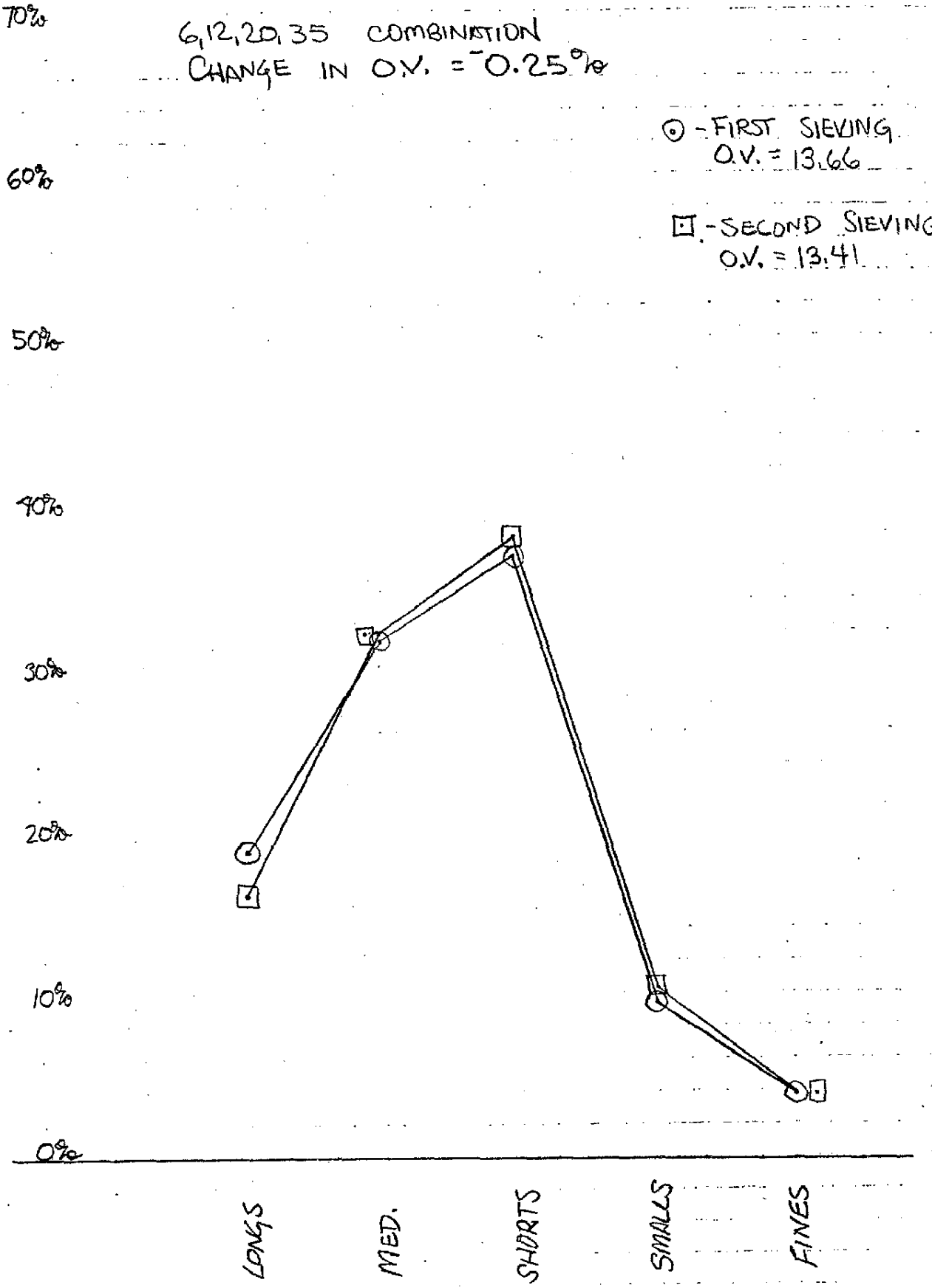
Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

6,12,20,35 COMBINATION
CHANGE IN O.V. = -0.25%

⊙ - FIRST SIEVING
O.V. = 13.66

⊡ - SECOND SIEVING
O.V. = 13.41



PM3000983871

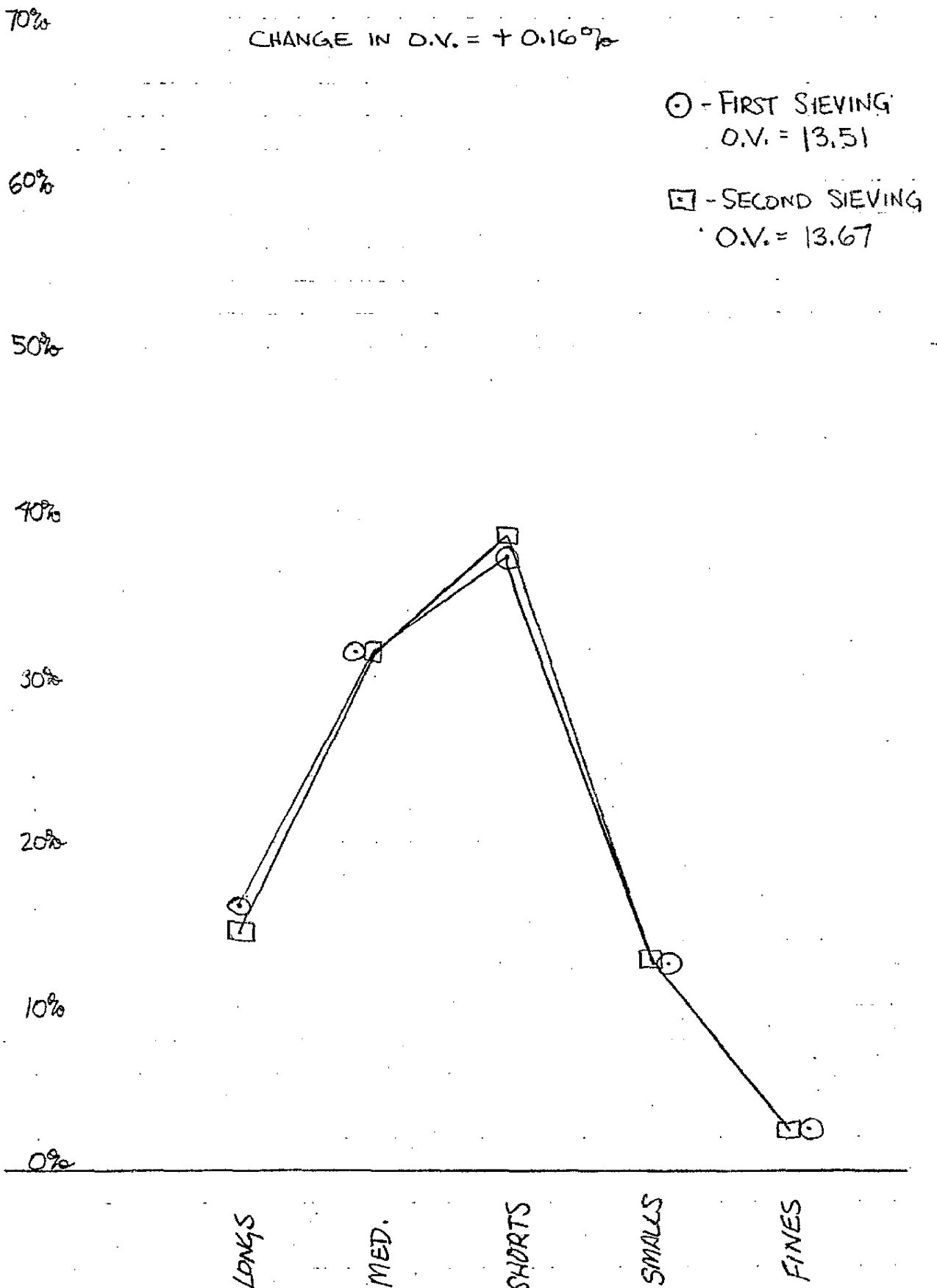
Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

6, 12, 20, 45 COMBINATION

CHANGE IN O.V. = + 0.16%

⊙ - FIRST SIEVING
O.V. = 13.51

⊡ - SECOND SIEVING
O.V. = 13.67

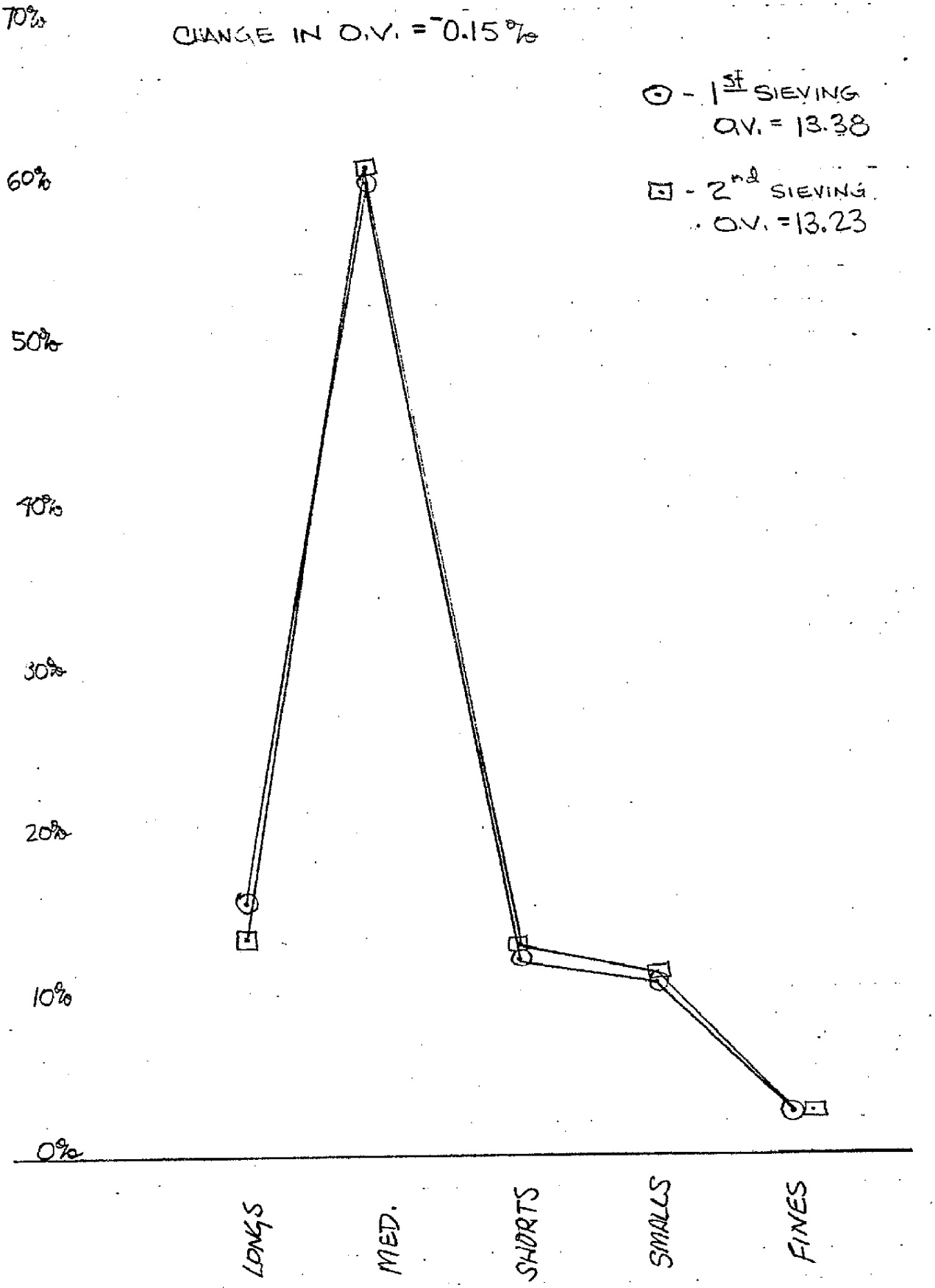


PM3000983872

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

6, 18, 20, 45 COMBINATION

CHANGE IN O.V. = -0.15%



PM3000983873

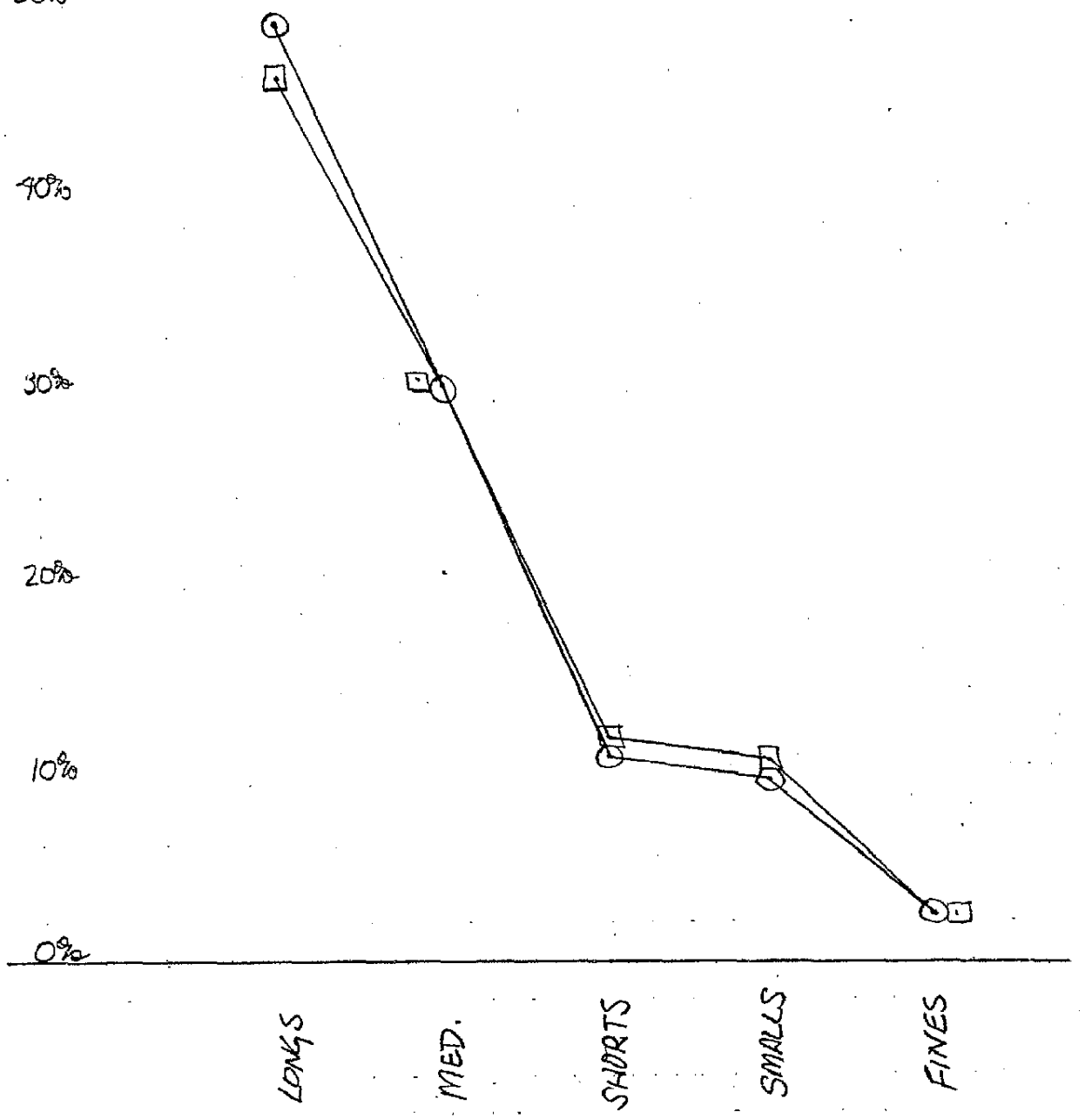
Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

12, 18, 20, 45 COMBINATION

CHANGE IN O.V. = -0.08 %

⊙ - FIRST SIEVING
O.V. = 13.21 %

⊡ - SECOND SIEVING
O.V. = 13.13 %



PM3000983874

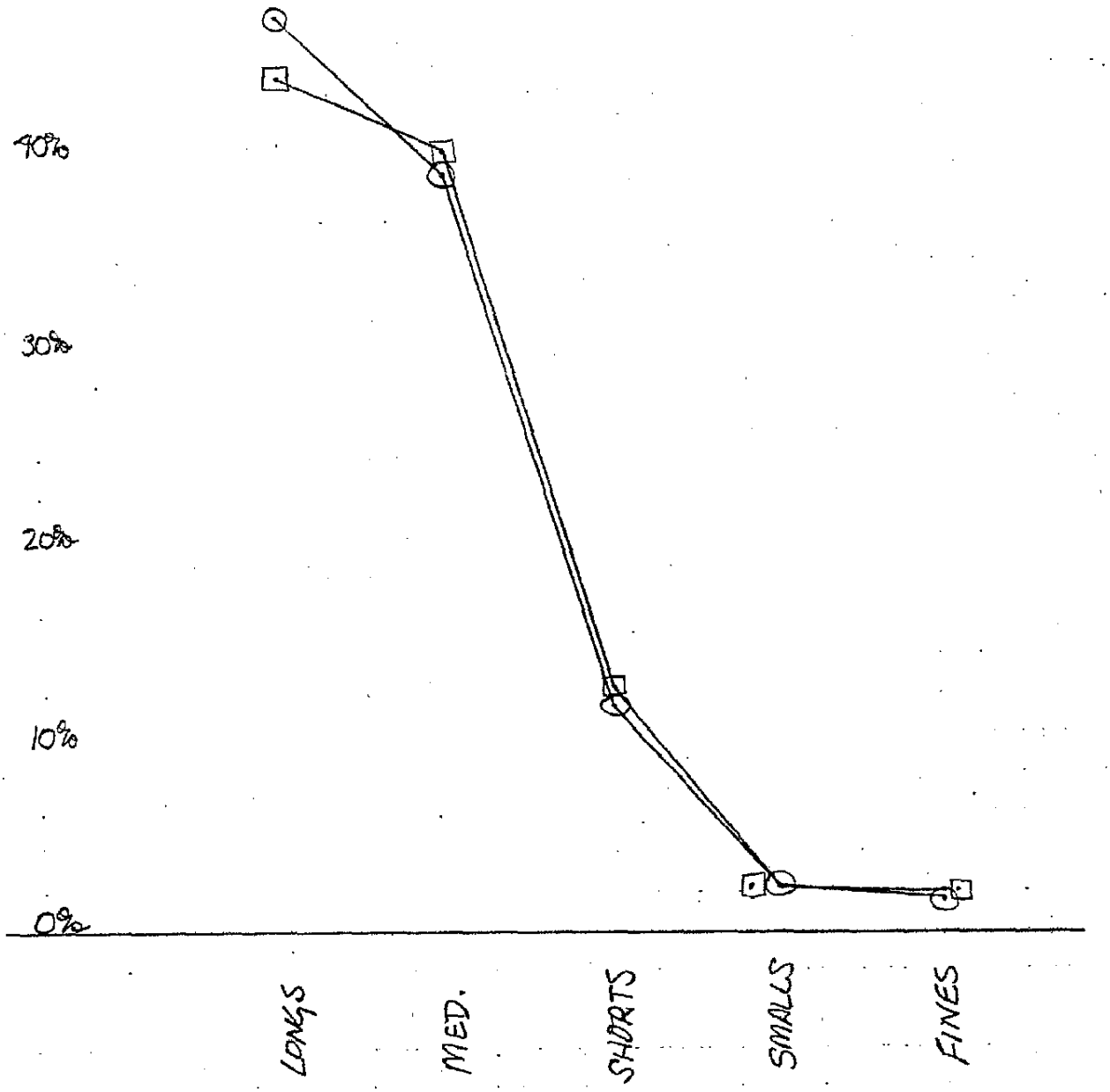
Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

12, 20, 35, 50 Combination

Change in O.V. = -0.62%

⊙ - First Sieving
O.V. = 13.96

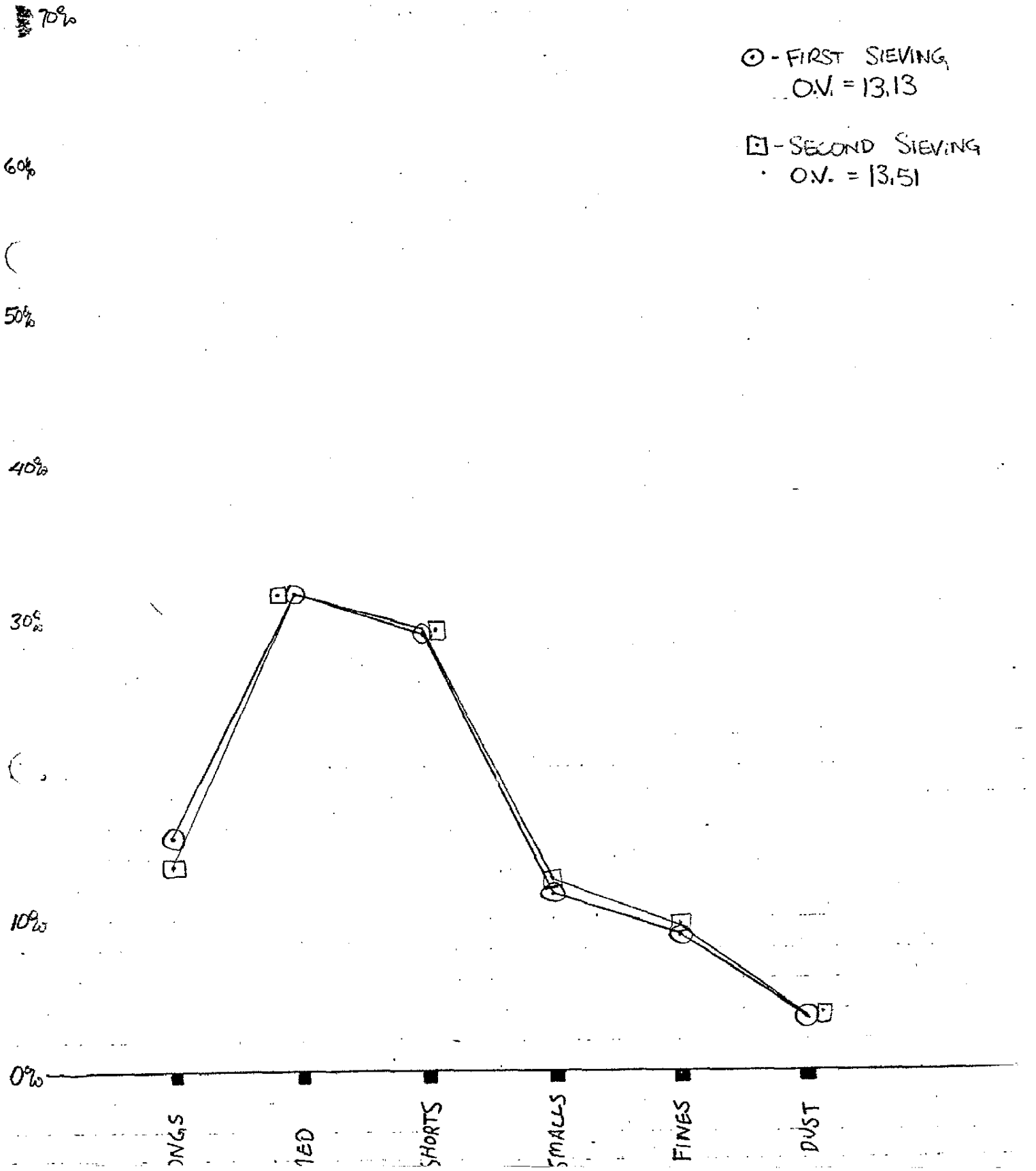
⊡ - Second Sieving
O.V. = 13.34



PM3000983875

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

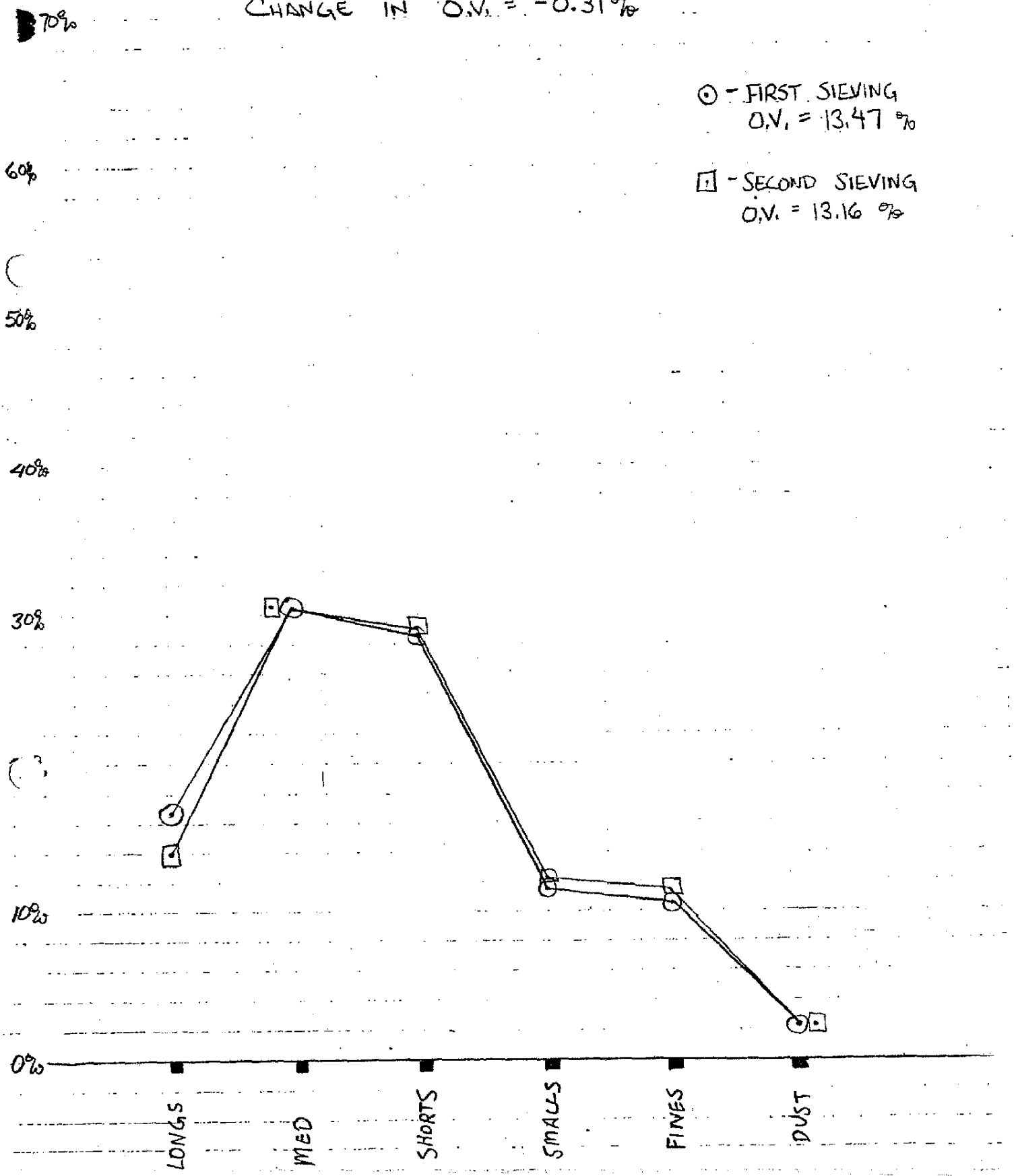
6, 12, 18, 20, 35 COMBINATION
CHANGE IN O.V. = +0.38



PM3000983876

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

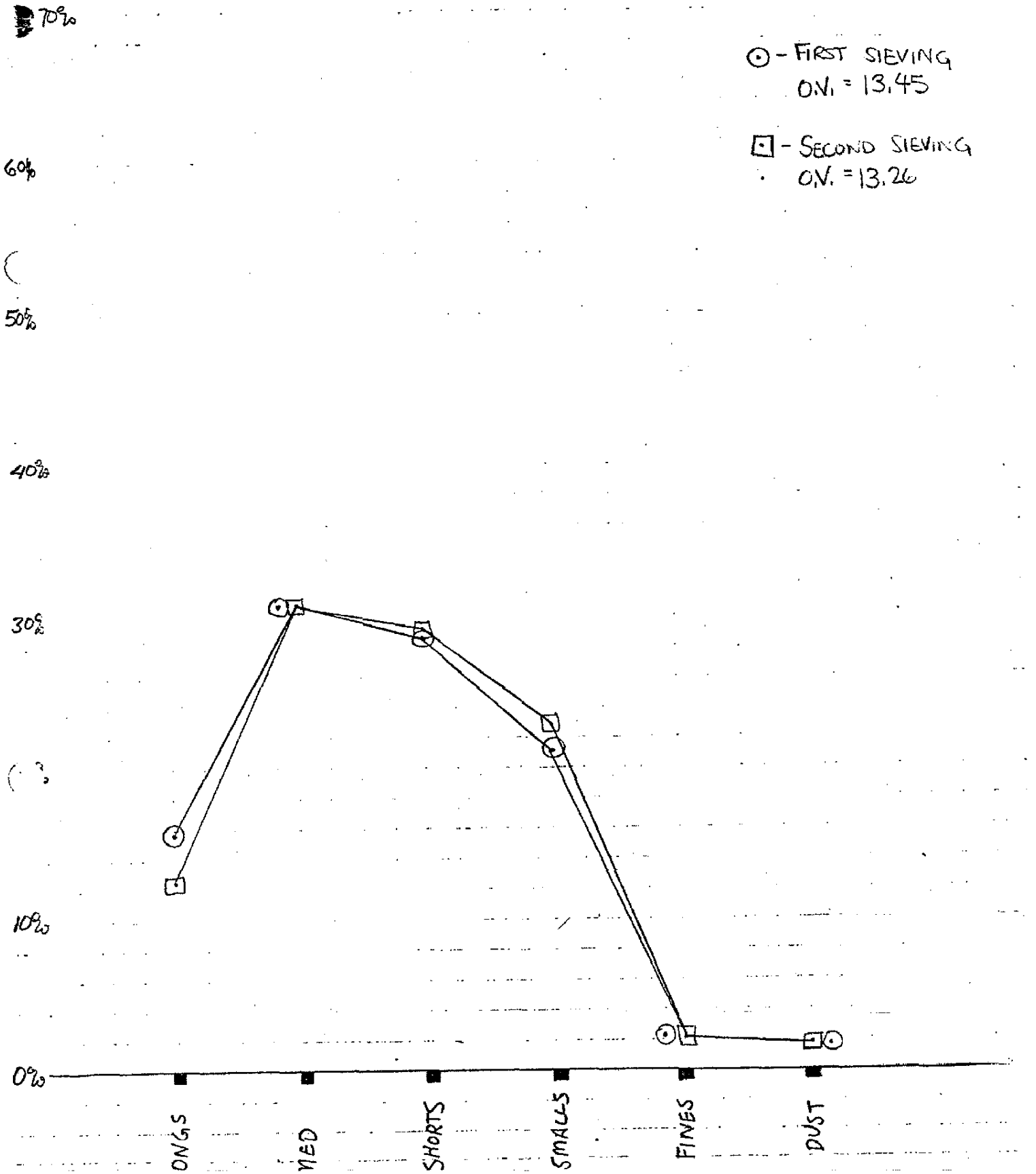
6,12,18,20,45 COMBINATION
CHANGE IN O.V. = -0.31%



PM3000983877

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

6, 12, 18, 35, 50 COMBINATION
CHANGE IN O.V. = -0.19



PM3000983878

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

APPENDIX V

Degradation Test Results

Mesh Combination	Sieving	% Longs	S.D.	% Mediums	S.D.	% Smalls	S.D.	% Shorts	S.D.	% Fines	S.D.
MKS-FB/150g											
6, 12, 18, 35	1	16.63	0.64	30.46	0.43	28.28	0.35	20.63	0.35	4.00	0.20
	2	14.52	0.64	30.57	0.55	28.91	0.32	21.88	0.31	4.11	0.20
6, 12, 20, 35	1	18.33	1.05	31.66	0.48	36.71	0.56	9.60	0.42	3.71	0.28
	2	16.08	1.06	31.91	0.31	37.82	0.61	10.36	0.41	3.83	0.29
6, 12, 20, 45	1	16.63	1.13	31.43	0.44	37.36	0.72	12.26	0.49	2.31	0.11
	2	14.60	0.96	31.44	0.44	38.65	0.68	12.97	0.43	2.35	0.13
6, 18, 20, 45	1	15.41	1.15	59.84	0.81	12.16	0.45	10.22	0.43	2.37	0.09
	2	13.21	0.79	60.57	0.57	12.83	0.32	10.97	0.45	2.42	0.11
12, 18, 20, 45	1	47.70	0.66	29.66	0.43	10.84	0.26	9.57	0.32	2.23	0.11
	2	45.76	0.60	29.96	0.30	11.41	0.21	10.56	0.40	2.31	0.10
12, 20, 35, 50	1	45.10	1.23	38.89	0.65	11.87	0.46	2.26	0.16	1.88	0.09
	2	43.44	1.32	39.79	0.69	12.56	0.48	2.29	0.15	1.92	0.11
6, 12, 18, 20, 35	1	15.32	1.24	31.69	0.60	28.71	0.41	11.89	0.25	8.77	0.40	3.62	0.17
	2	13.41	1.29	31.64	0.62	29.22	0.42	12.57	0.32	9.45	0.30	3.72	0.17
6, 12, 18, 20, 45	1	16.16	1.24	30.65	0.43	28.64	0.53	11.66	0.32	10.60	0.38	2.29	0.15
	2	14.03	1.18	30.71	0.53	29.28	0.47	12.19	0.33	11.43	0.41	2.36	0.14
6, 12, 18, 35, 50	1	14.74	0.94	31.01	0.69	28.79	0.28	21.54	0.55	2.15	0.14	1.77	0.09
	2	12.65	0.80	30.97	0.52	29.39	0.26	22.99	0.53	2.18	0.14	1.83	0.09

(Cont'd.)

PM3000983879

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

APPENDIX V (Cont'd.)

Mesh Combination	Sieving	% Longs	S.D.	% Mediums	S.D.	% Smalls	S.D.	% Shorts	S.D.	% Fines	S.D.
MKS-FB/100g											
6, 12, 18, 35	1	15.32	1.02	32.36	0.66	28.55	0.46	20.17	0.55	3.60	0.26
	2	12.60	0.82	32.38	0.72	29.30	0.43	22.06	0.66	3.66	0.24
6, 12, 20, 35	1	13.27	1.07	31.66	0.57	39.78	0.76	11.45	0.49	3.85	0.26
	2	11.36	0.95	30.75	0.54	41.35	0.71	12.62	0.46	3.92	0.27
MKS-FB/50g											
6, 12, 18, 35	1	8.65	1.04	34.44	0.41	31.58	0.56	21.87	0.51	3.48	0.27
	2	7.22	0.70	32.32	0.50	32.20	0.55	24.62	0.45	3.65	0.25
MKS-FB/200g											
6, 12, 18, 35	1	19.44	0.67	30.71	0.42	27.08	0.22	19.07	0.44	3.70	0.19
	2	16.95	0.40	31.38	0.37	27.73	0.36	20.14	0.36	3.81	0.19
MKS-ES/100g											
6, 12, 18, 35	1	5.27	0.50	29.74	1.16	33.52	0.59	27.66	0.96	3.80	0.82
	2	4.25	0.43	28.16	1.29	34.05	0.47	29.79	1.00	3.75	0.81
6, 12, 20, 35	1	13.42	1.43	33.49	0.69	40.01	1.11	10.90	0.53	2.19	0.29
	2	11.34	1.48	32.56	0.72	41.73	1.06	12.19	0.51	2.19	0.30
MKS-ES/50g											
6, 12, 18, 35	1	5.63	0.41	30.84	1.06	34.03	0.89	26.55	1.01	2.95	0.68
	2	4.53	0.35	28.69	1.20	34.30	0.79	29.47	1.03	3.02	0.72

(Cont'd.)

PM3000983880

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

APPENDIX V (Cont'd.)

Mesh Combination	Sieving	% Longs	S.D.	% Mediums	S.D.	% Smalls	S.D.	% Shorts	S.D.	% Fines	S.D.
MKS-ES/200g											
6, 12, 18, 35	1	9.79	1.30	33.62	0.84	30.75	0.67	22.79	0.90	3.05	0.41
	2	8.21	1.15	33.24	0.81	31.35	0.60	24.08	0.97	3.14	0.42
DIET/100g											
6, 12, 18, 35	1	7.97	0.55	33.67	0.61	34.22	0.59	22.12	0.66	2.03	0.35
	2	7.41	0.41	33.40	0.65	34.63	0.55	22.59	0.64	1.97	0.35
6, 12, 20, 35	1	7.38	0.91	32.19	1.78	47.30	1.24	11.27	1.21	1.86	0.41
	2	6.67	0.75	31.81	1.76	48.22	1.11	11.53	1.13	1.78	0.42
DIET/50g											
6, 12, 18, 35	1	7.81	0.67	31.95	0.74	34.64	0.31	23.77	0.88	1.83	0.23
	2	6.91	0.55	31.15	0.81	35.03	0.47	25.07	0.72	1.83	0.21
DIET/200g											
6, 12, 18, 35	1	8.18	0.32	37.80	0.48	37.67	0.34	19.66	0.43	1.69	0.14
	2	7.64	0.29	37.53	0.56	33.14	0.39	20.01	0.44	1.68	0.13

PM3000983881

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

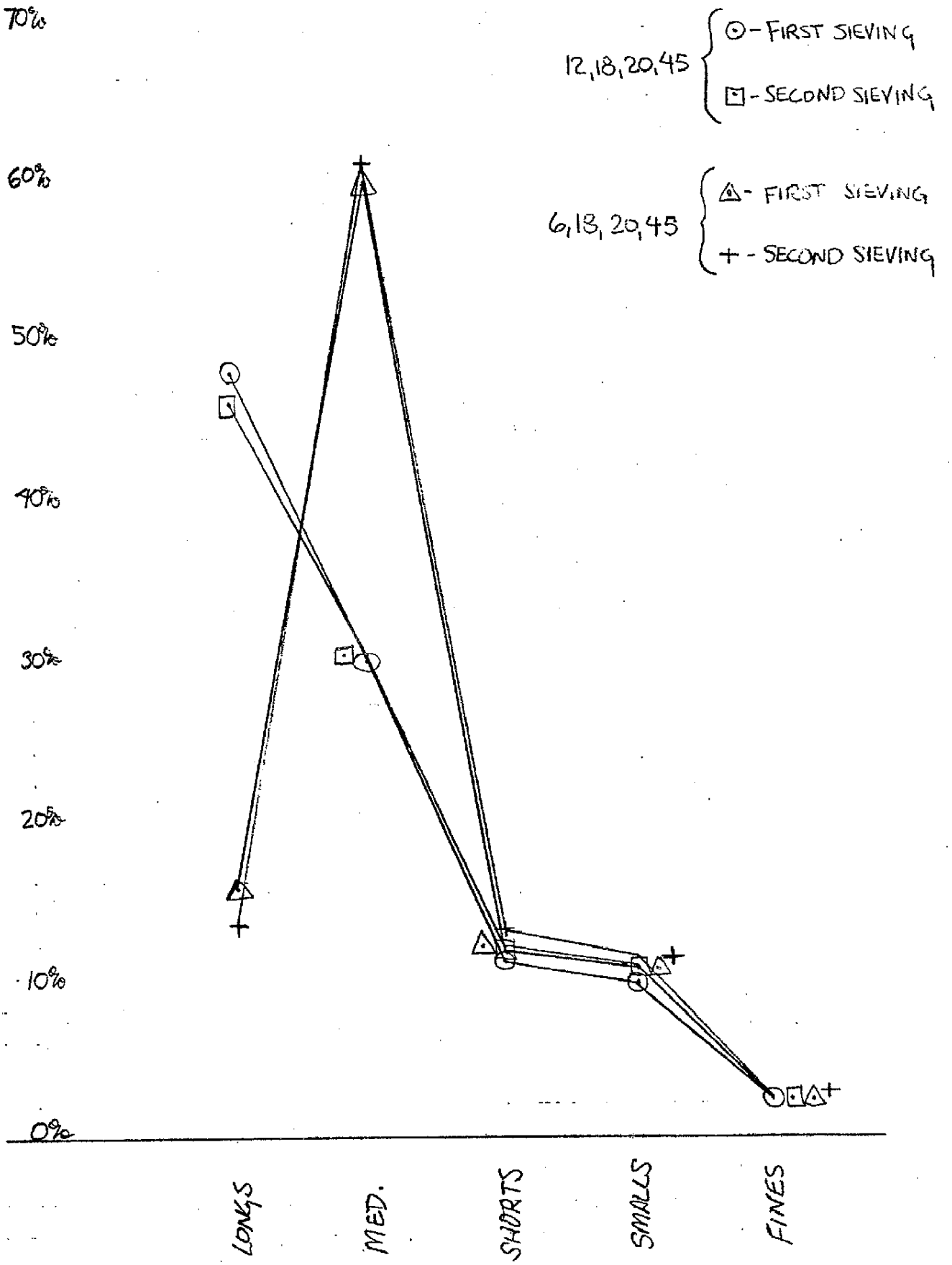
APPENDIX VI

Degradation Graphs

PM3000983882

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

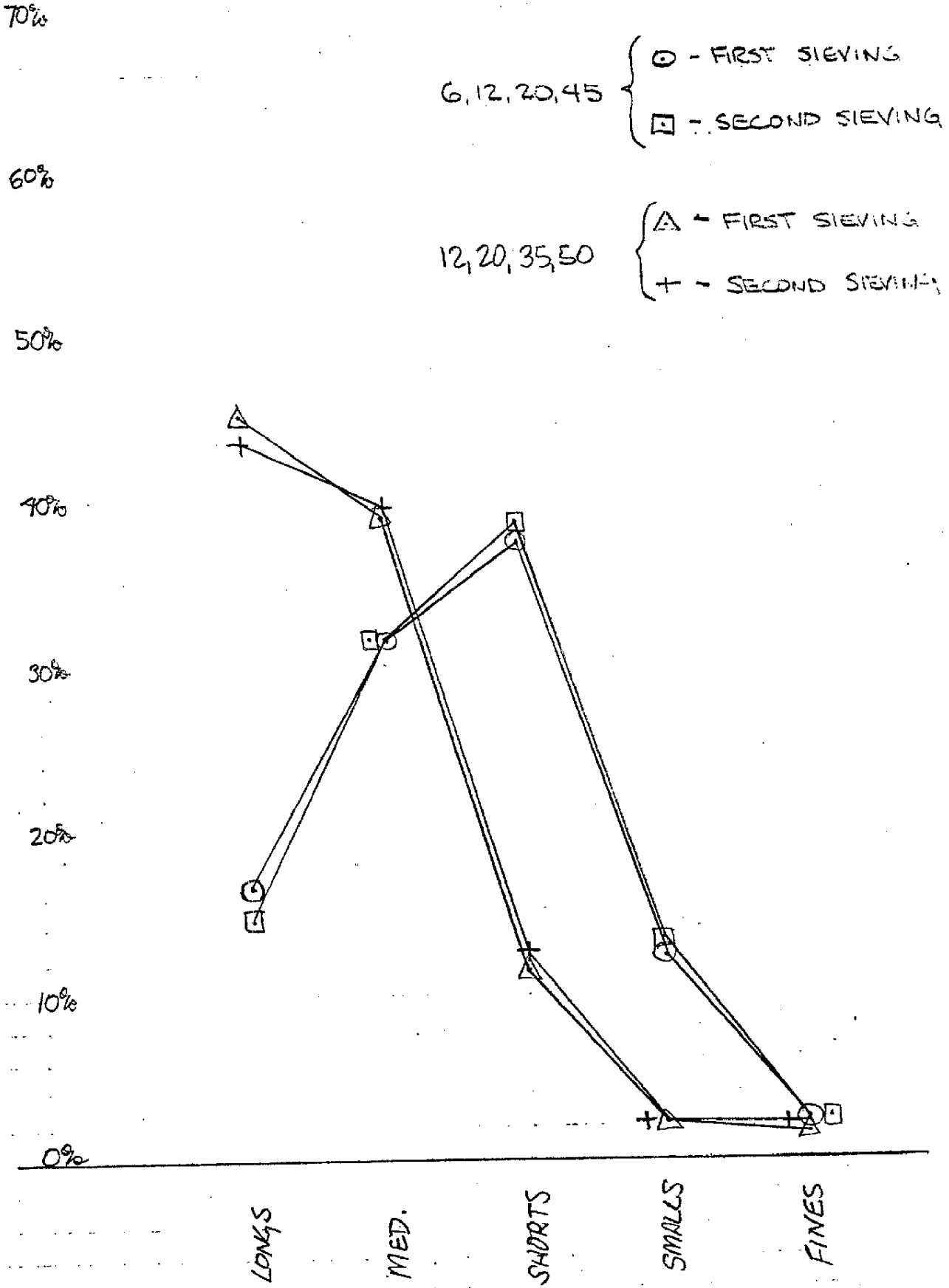
DEGRADATION TEST
MKS-FB /150g



PM3000983883

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

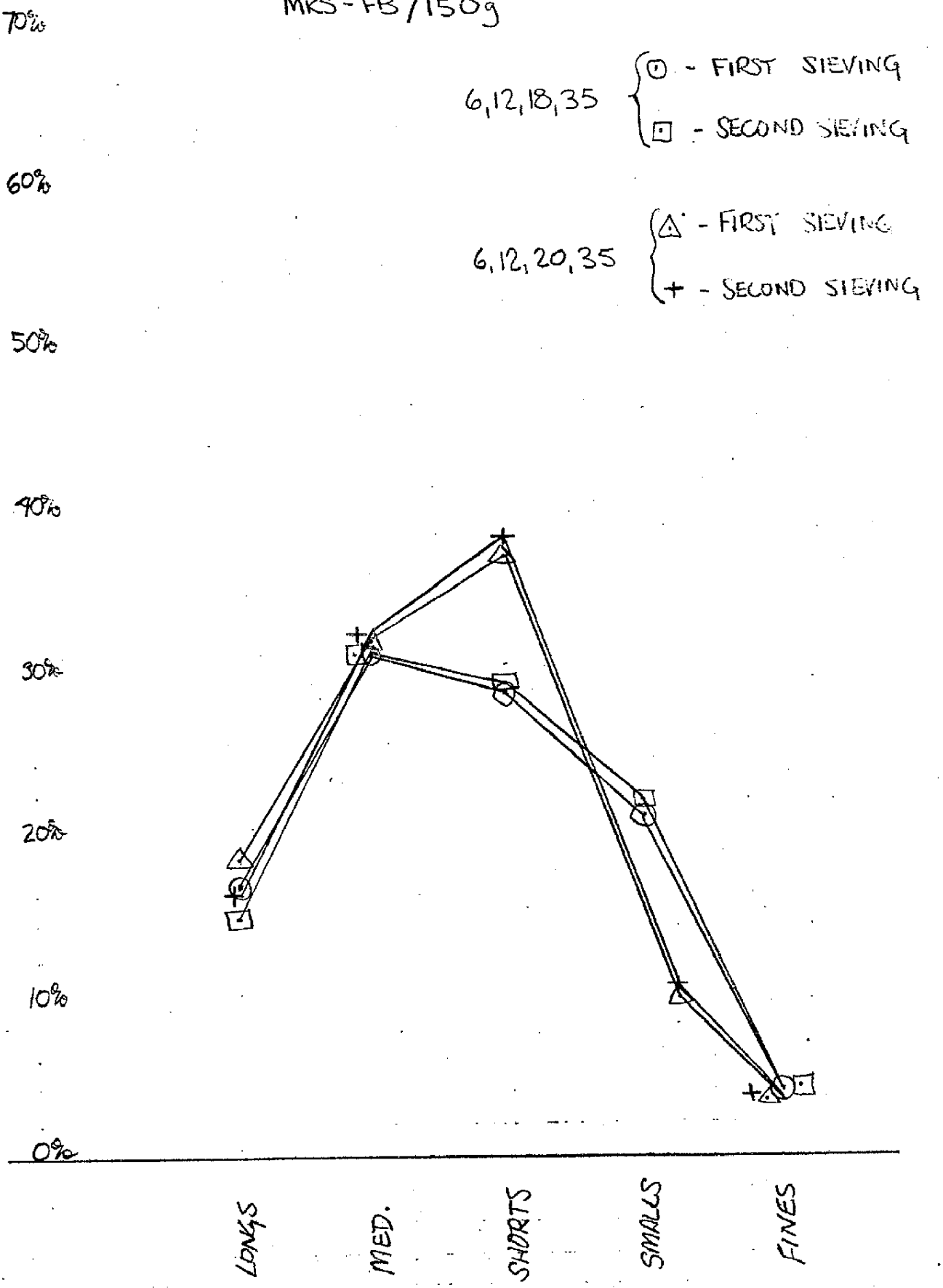
DEGRADATION TEST
MKS - FB / 150g



PM3000983884

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

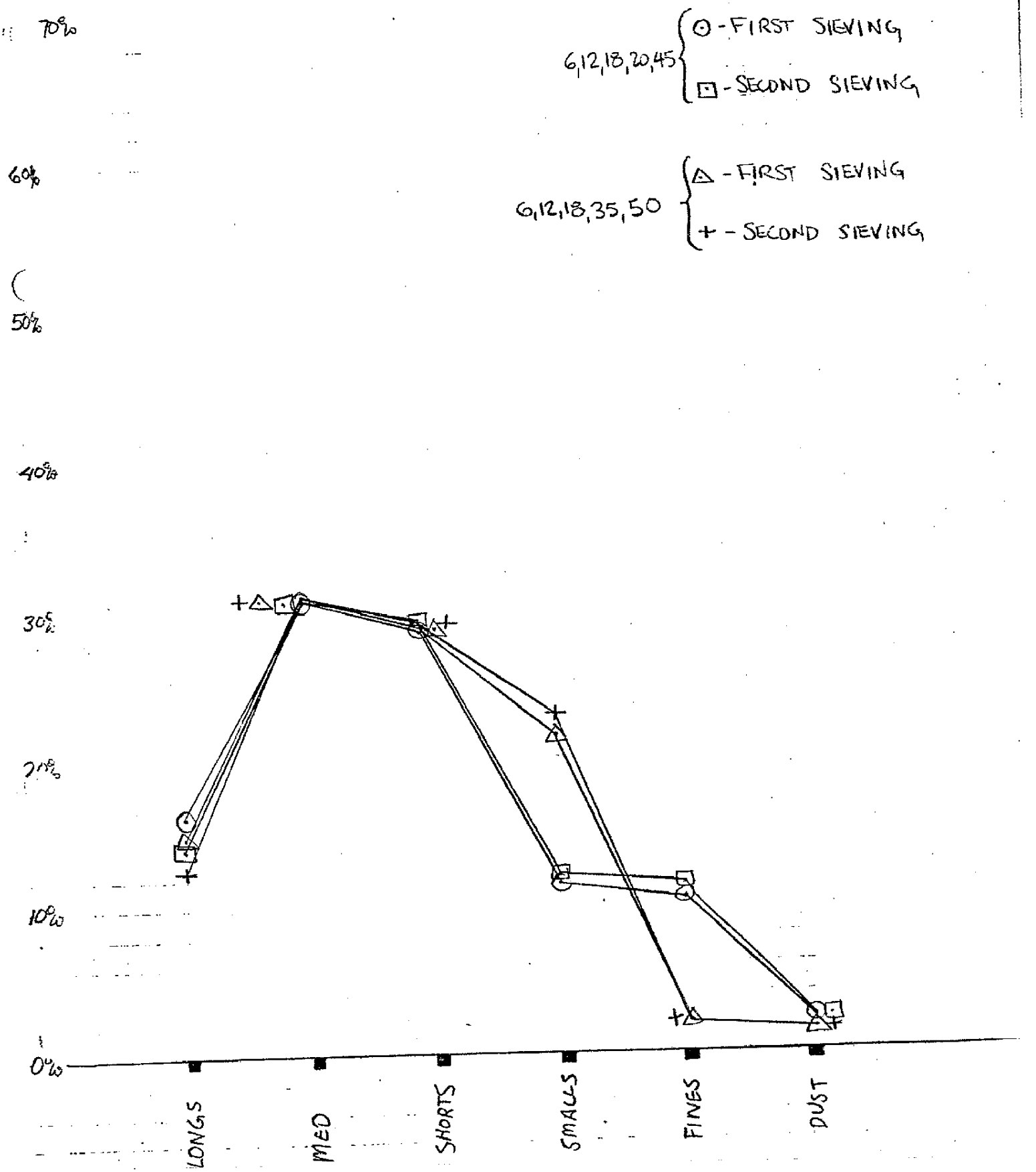
DEGRADATION TEST
MKS-FB/150g



PM3000983885

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

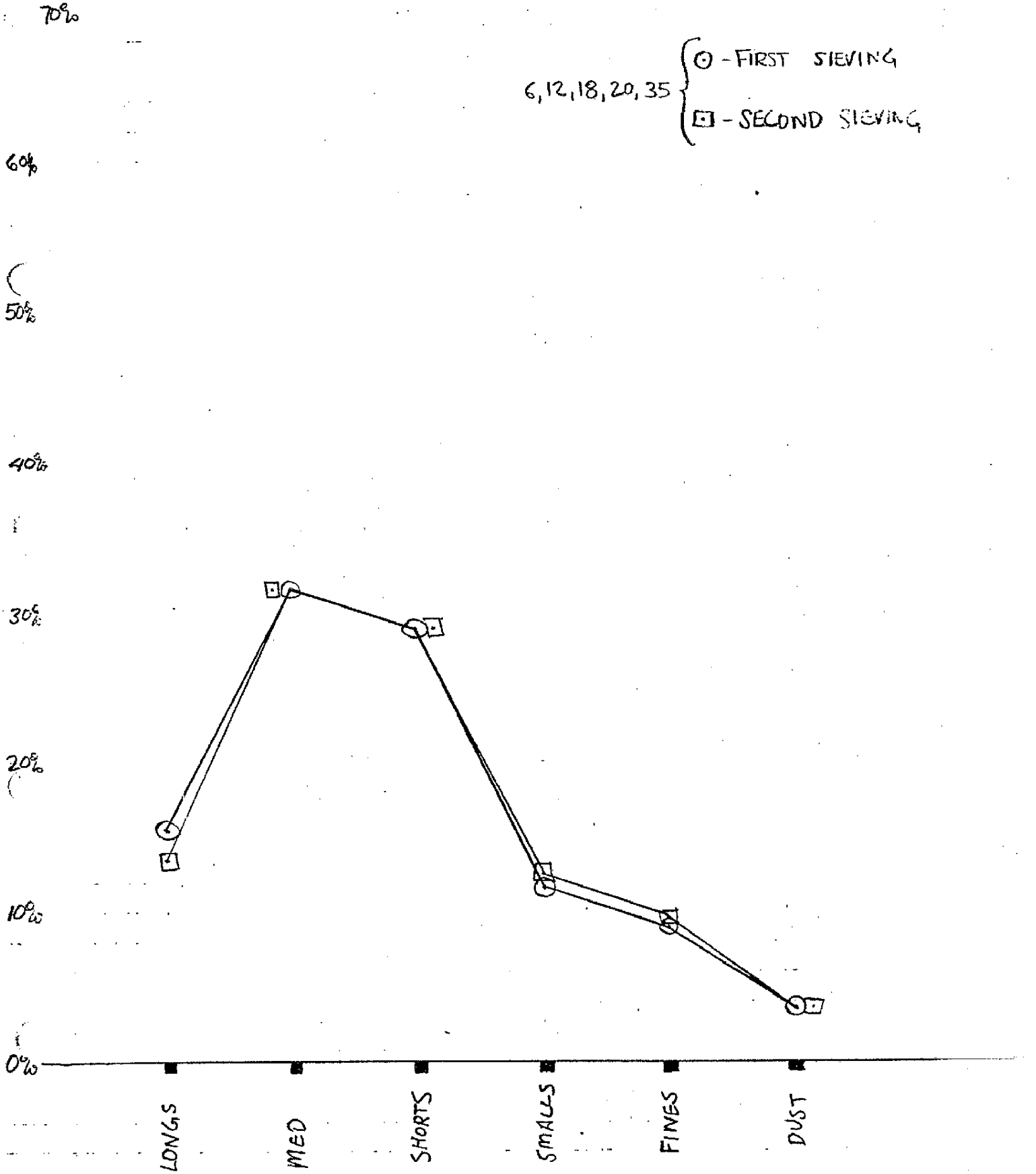
DEGRADATION TEST
MKS-FB/150g



PM3000983886

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

DEGRADATION TEST
MKS-FB/150g



PM3000983887

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

APPENDIX VII

Degradation Test
Sample Size Comparison

PM3000983888

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

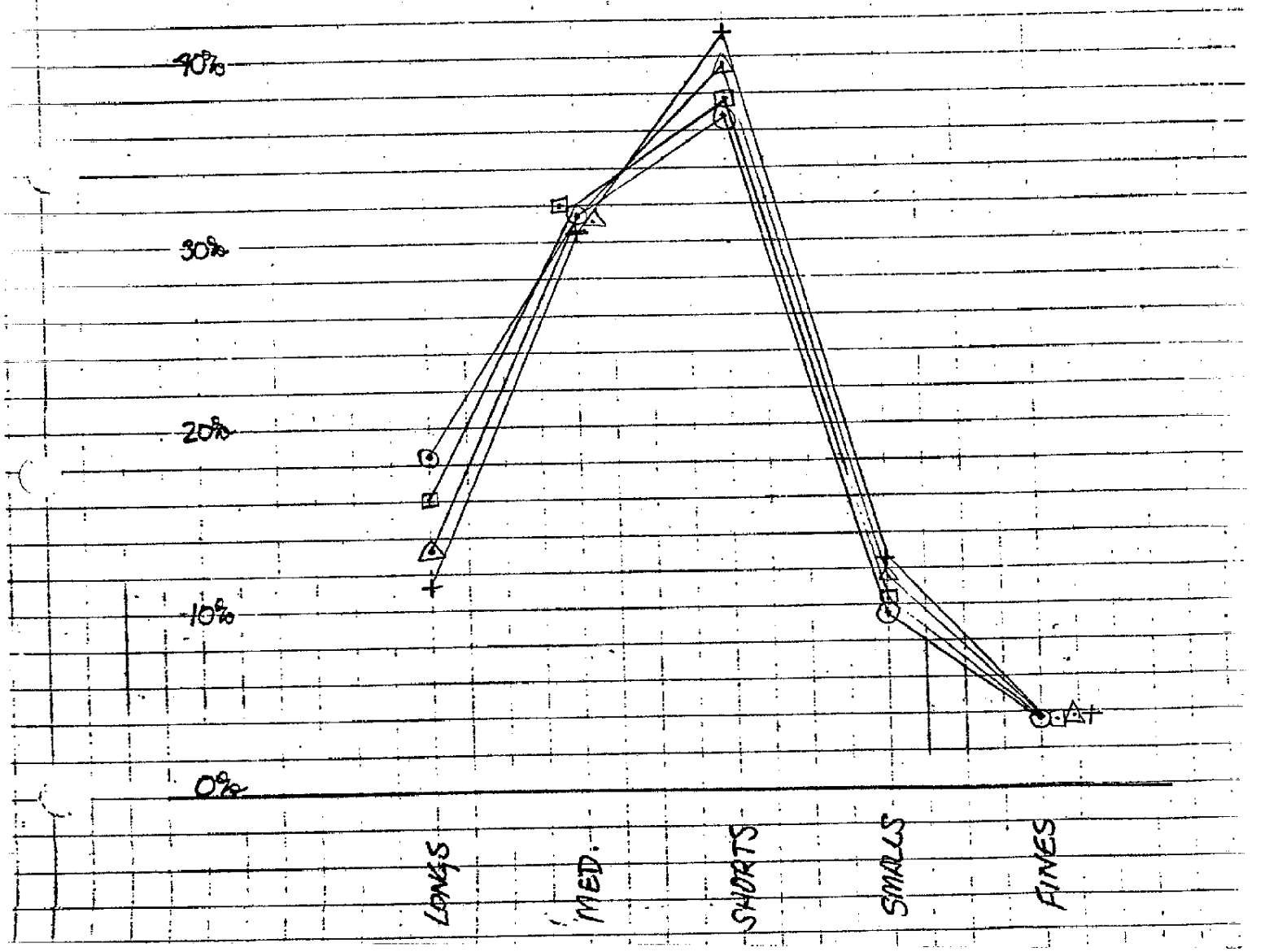
MKS - FB

⊙ - 150g ONE SHAKING 6,12,20,35

□ - 150g TWO SHAKINGS 6,12,20,35

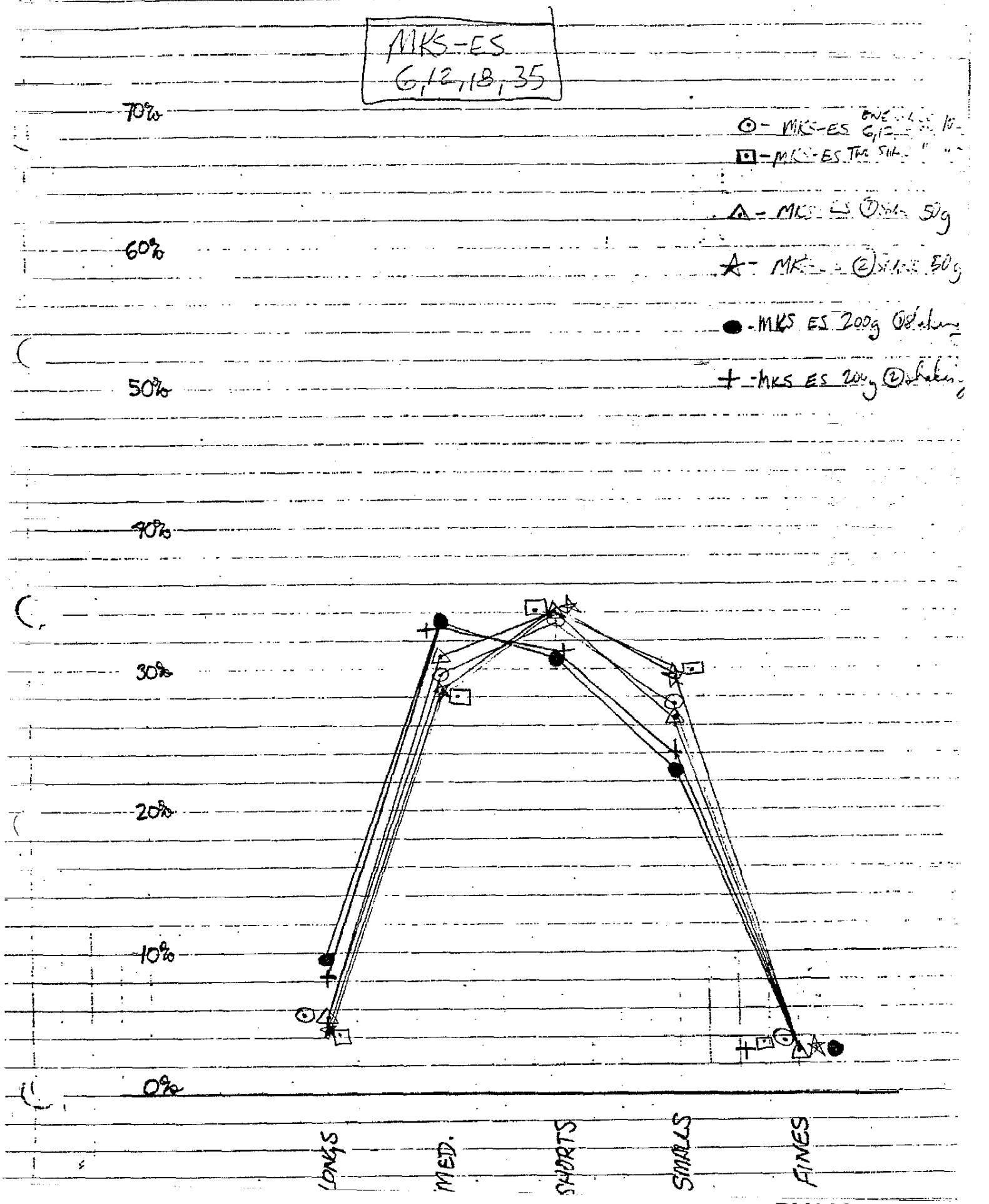
△ - 100g ONE SHAKING 6,12,20,35

\+ - 100g TWO SHAKINGS 6,12,20,35

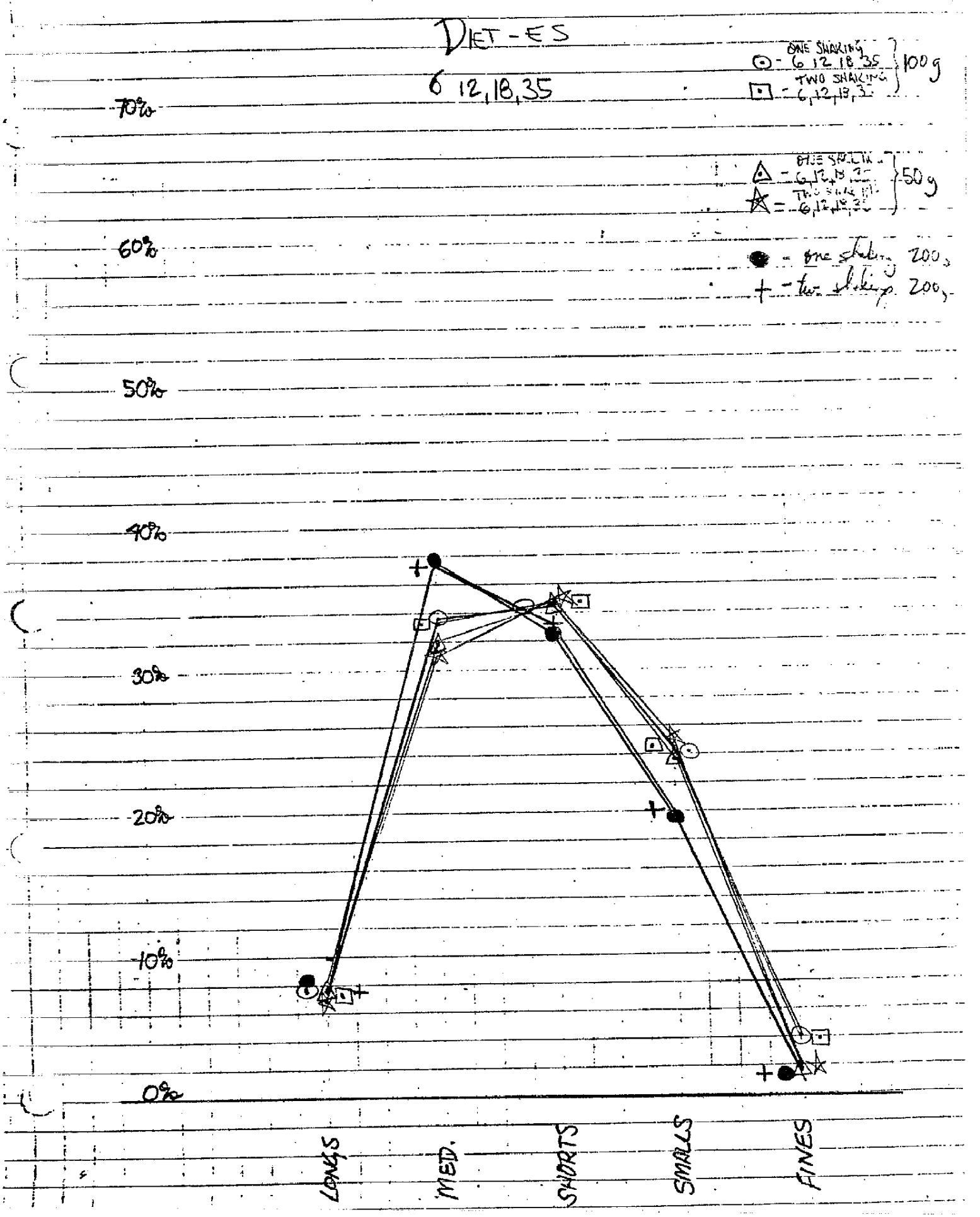


PM3000983889

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001



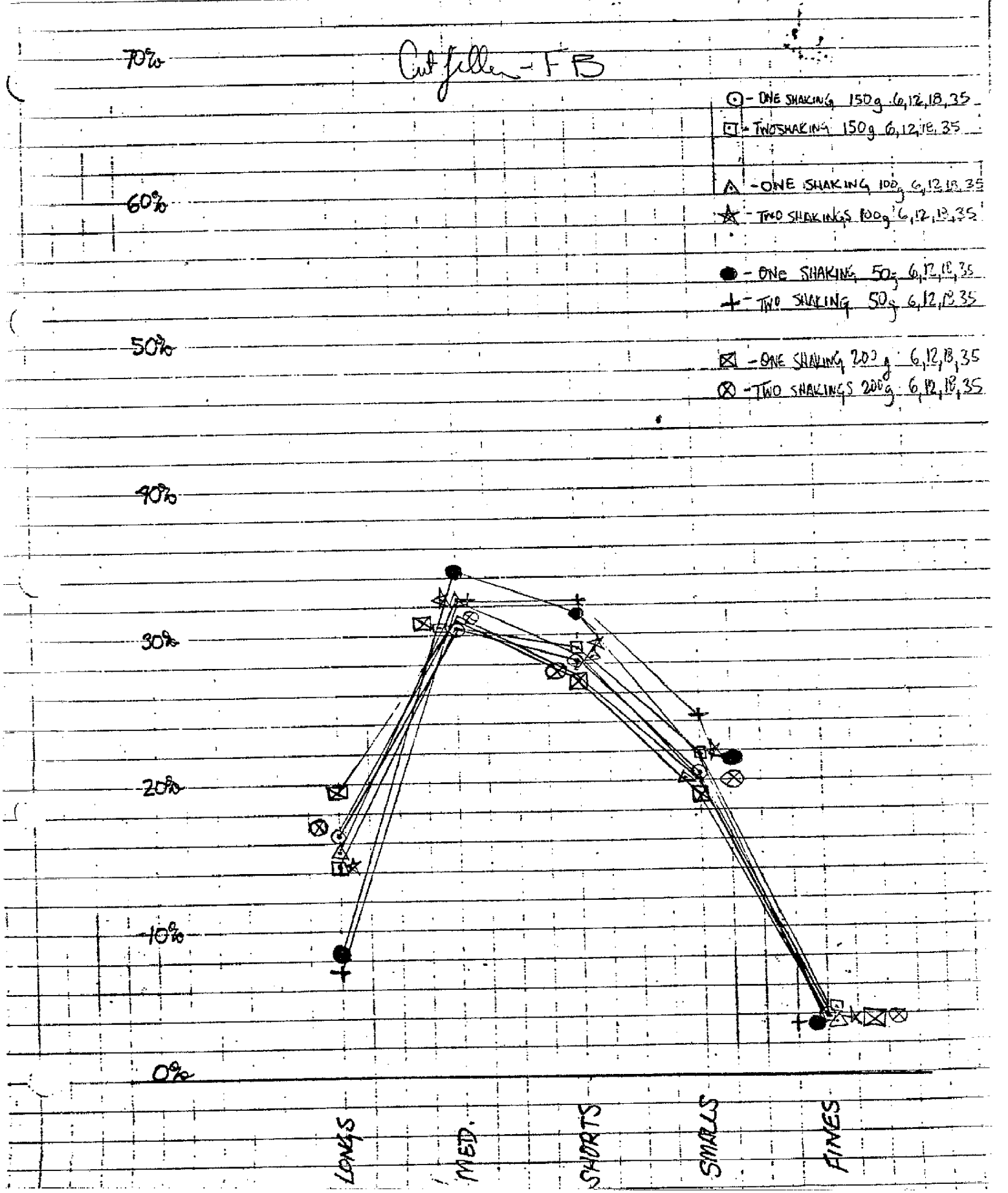
Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001



PM3000983891

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

Cut filler - FB



PM3000983892

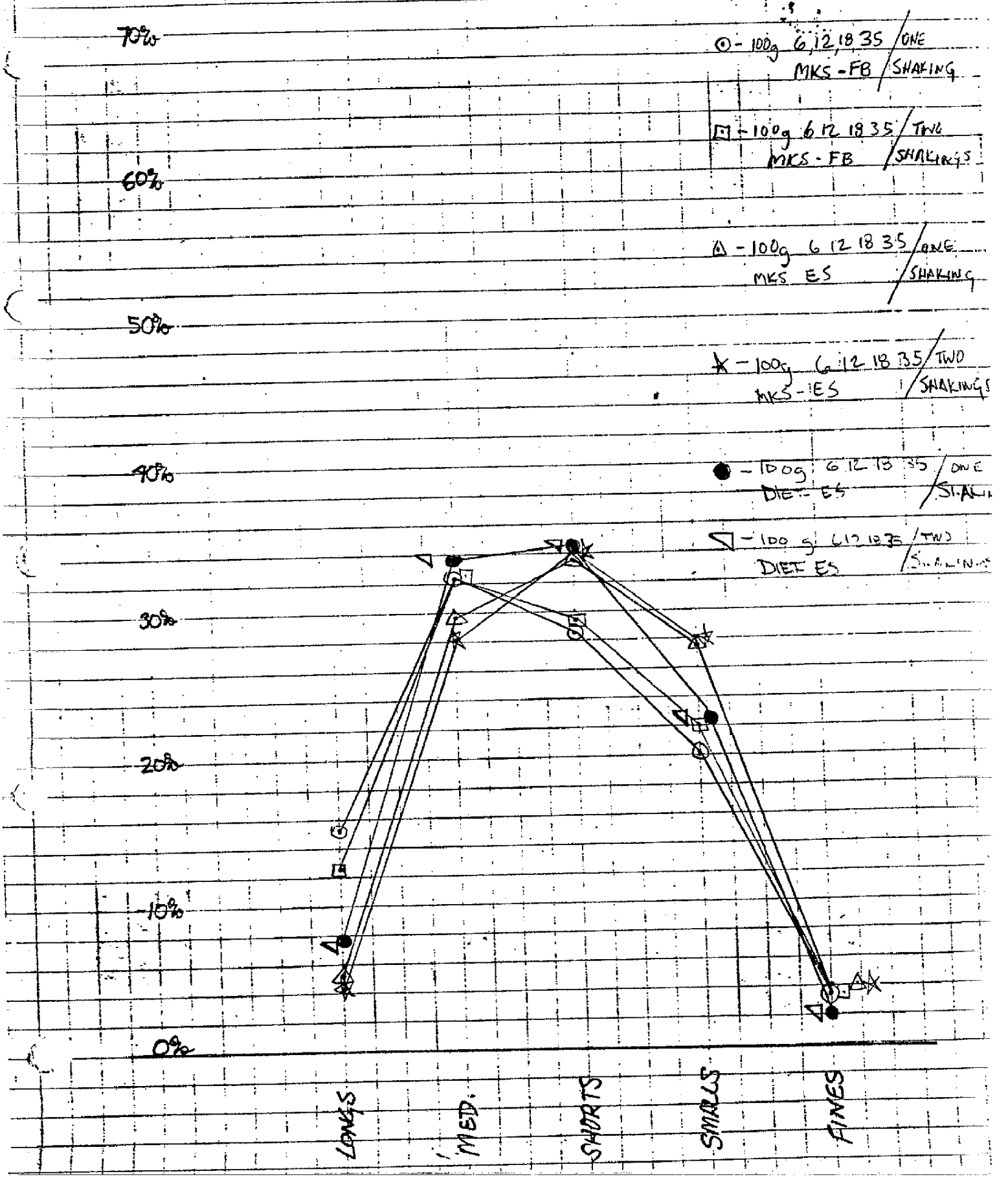
Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

APPENDIX VIII

Degradation Test
Product Comparison

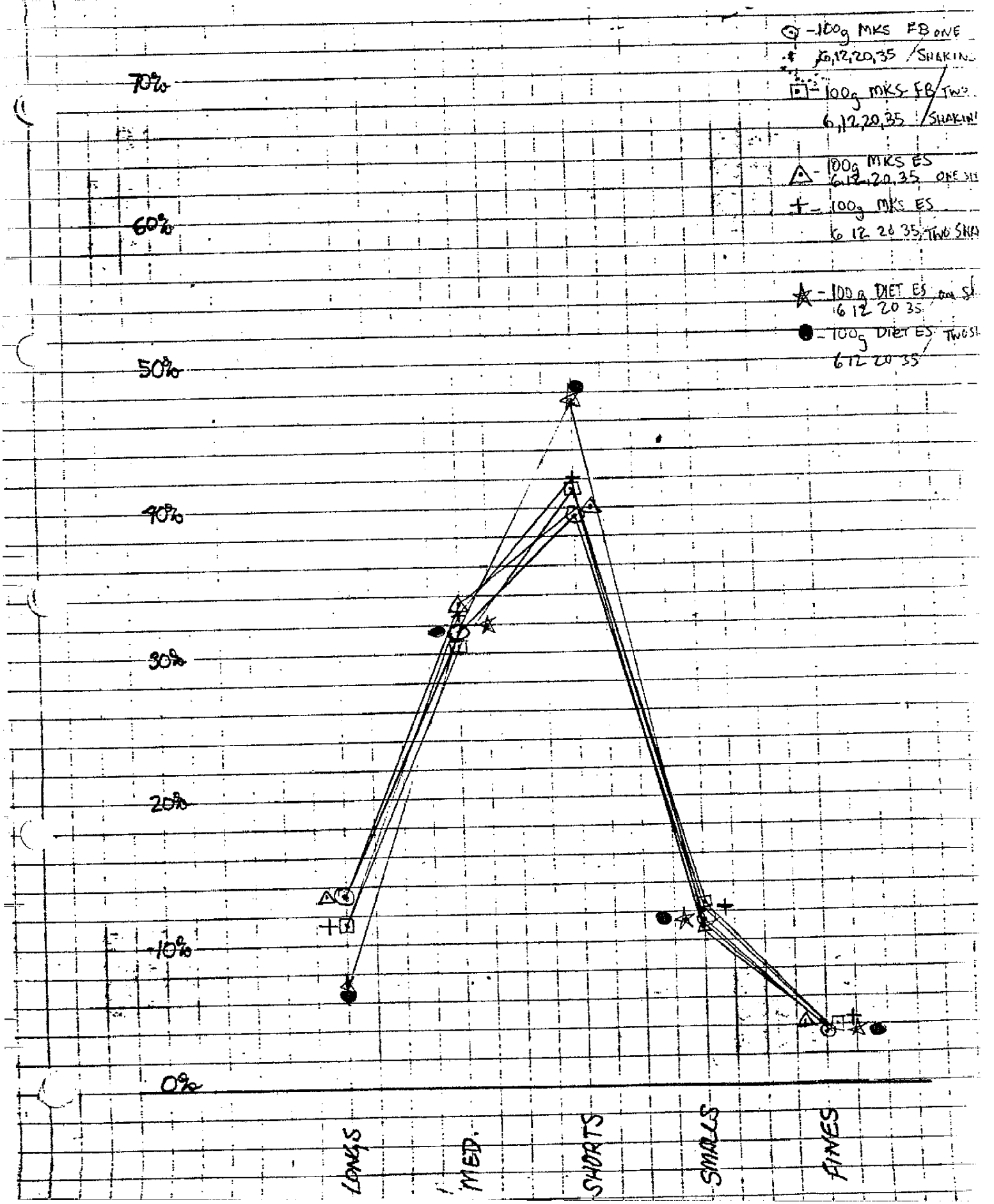
PM3000983893

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001



PM3000983894

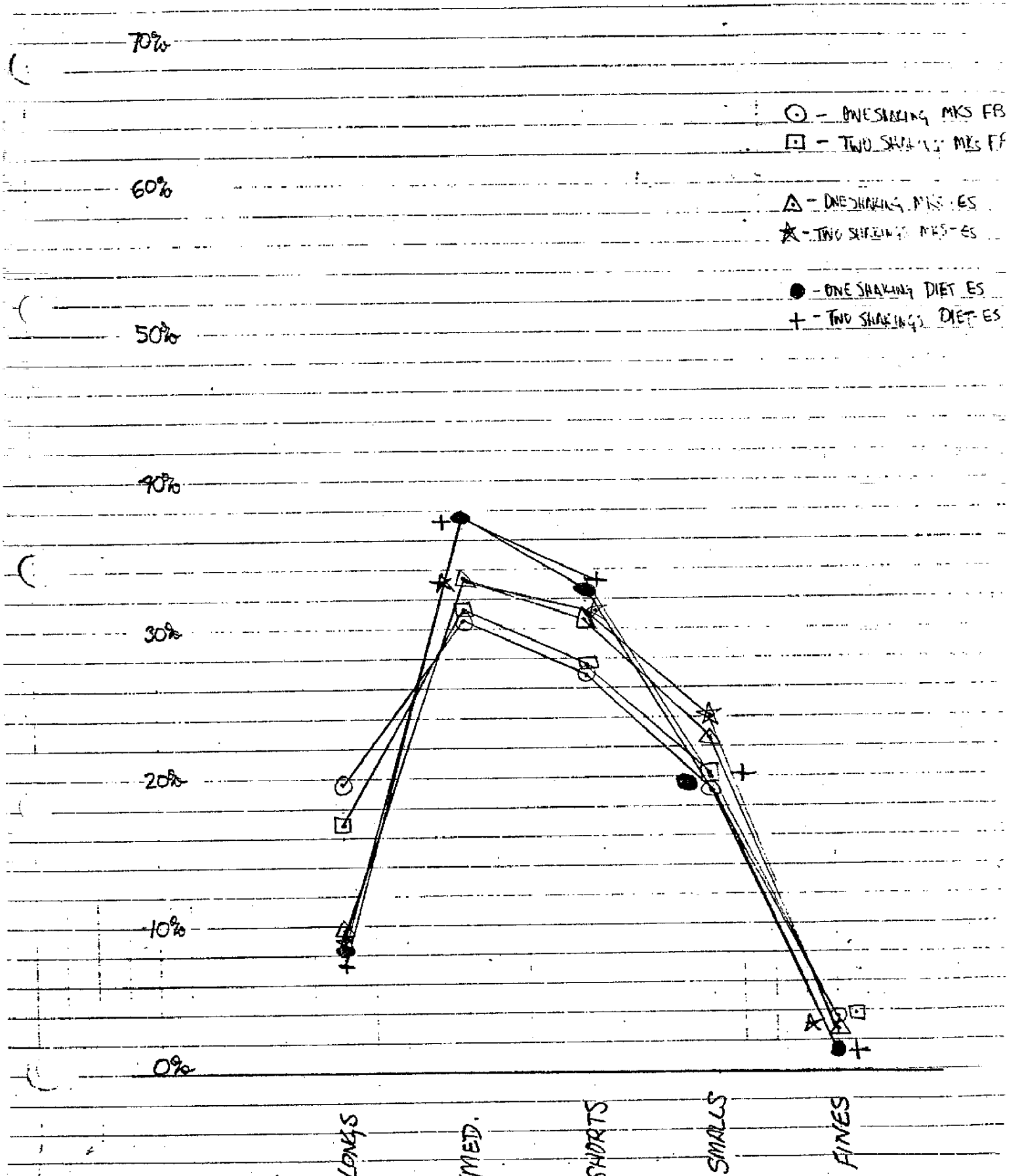
Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001



PM3000983895

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

200g 6,12,18,35



PM3000983896

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

50g
6, 12, 16, 35

70%

60%

50%

90%

30%

20%

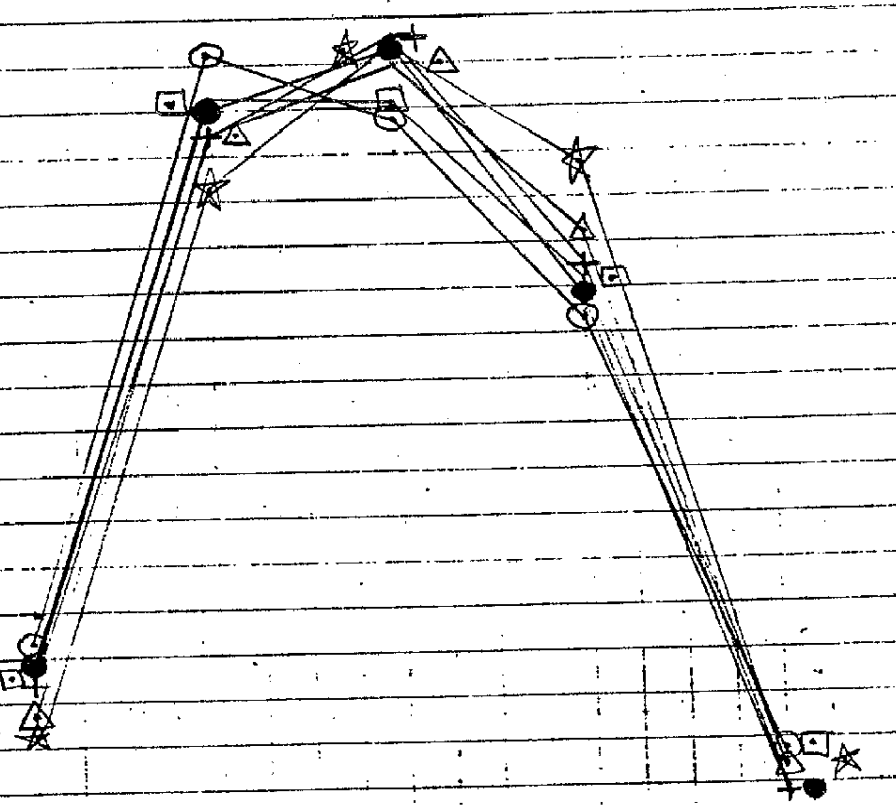
10%

0%

⊙ - ONE STRIKE
⊡ - TWO STRIKE
} MKS FB

△ - ONE STRIKE
★ - TWO STRIKE
} MKS-ES

● - ONE STRIKE
+ - TWO STRIKE
} DIEFES



LONGS
MED.
SHORTS
SMALLS
FINES

PM3000983897

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

APPENDIX IX

Comparison Test - Results

Mesh Combination	Trial	Set	% Longs	% Mediums	% Shorts	% Smalls	% Fines
MKS-FB/150g							
6, 12, 18, 35	1	1	15.59	31.76	28.55	20.05	4.06
	2	2	15.00	34.05	30.96	16.15	3.84
	1	1	15.27	31.14	28.95	20.76	3.88
	2	2	13.70	32.49	32.02	18.06	3.74
6, 12, 20, 35	1	1	16.40	30.54	37.78	11.08	4.21
	2	2	14.84	32.47	36.90	11.77	4.02
12, 18, 20, 45	1	2	46.38	31.81	7.57	11.60	2.64
	2	1	41.99	30.06	12.35	12.69	2.92
MKS-FB/100g							
6, 12, 18, 35	1	1	11.41	31.38	30.35	22.75	4.10
	2	2	10.51	31.30	34.19	20.06	3.94
Ripper Shorts/150g							
6, 12, 18, 35	1	1	0.80	18.90	43.32	36.44	0.55
	2	2	0.83	19.90	49.16	29.64	0.47

PM3000983898

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

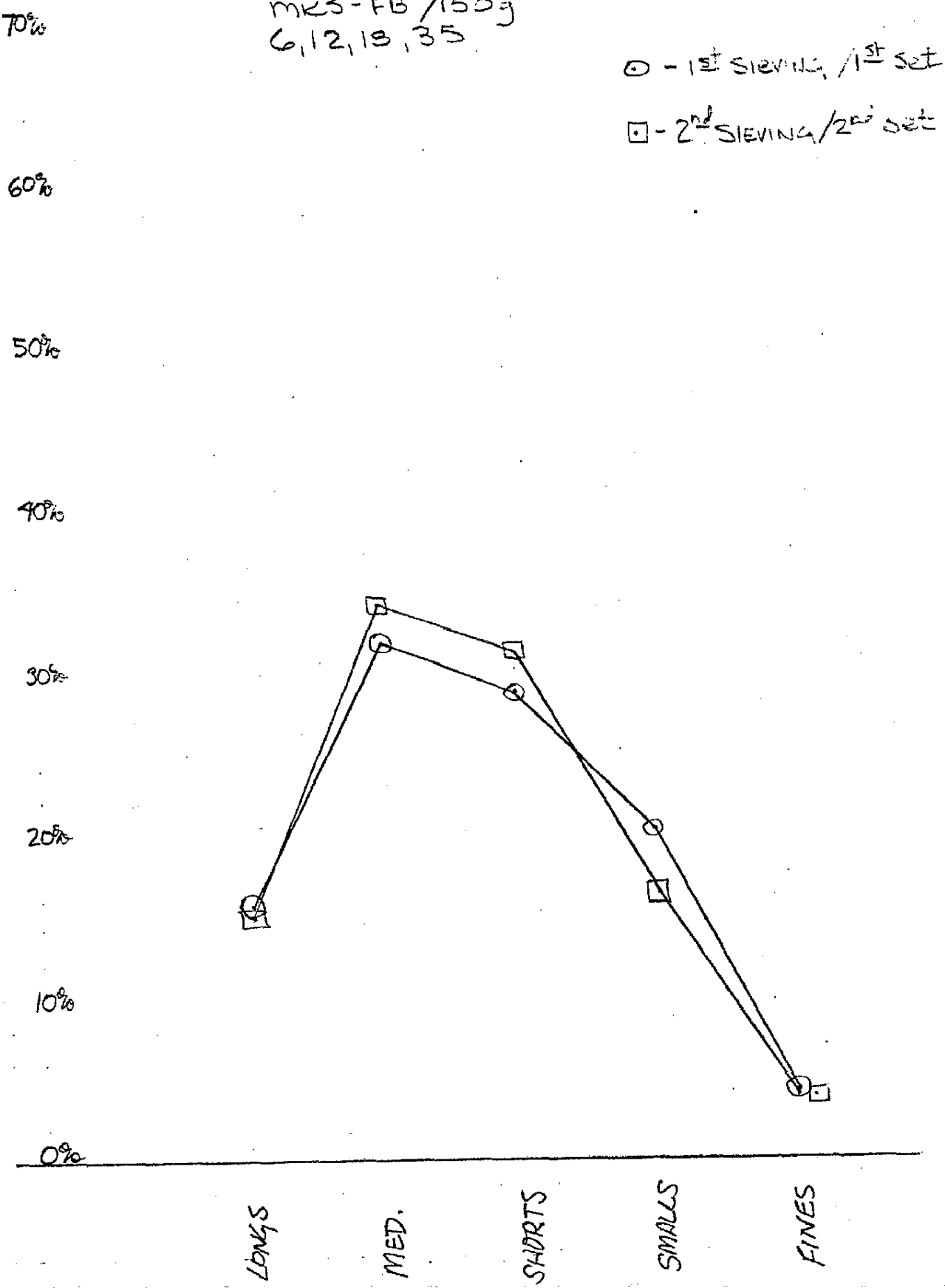
APPENDIX X

Comparison Test - Graphs

PM3000983899

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

COMPARISON TEST
MKS-FB/150g
6, 12, 18, 35



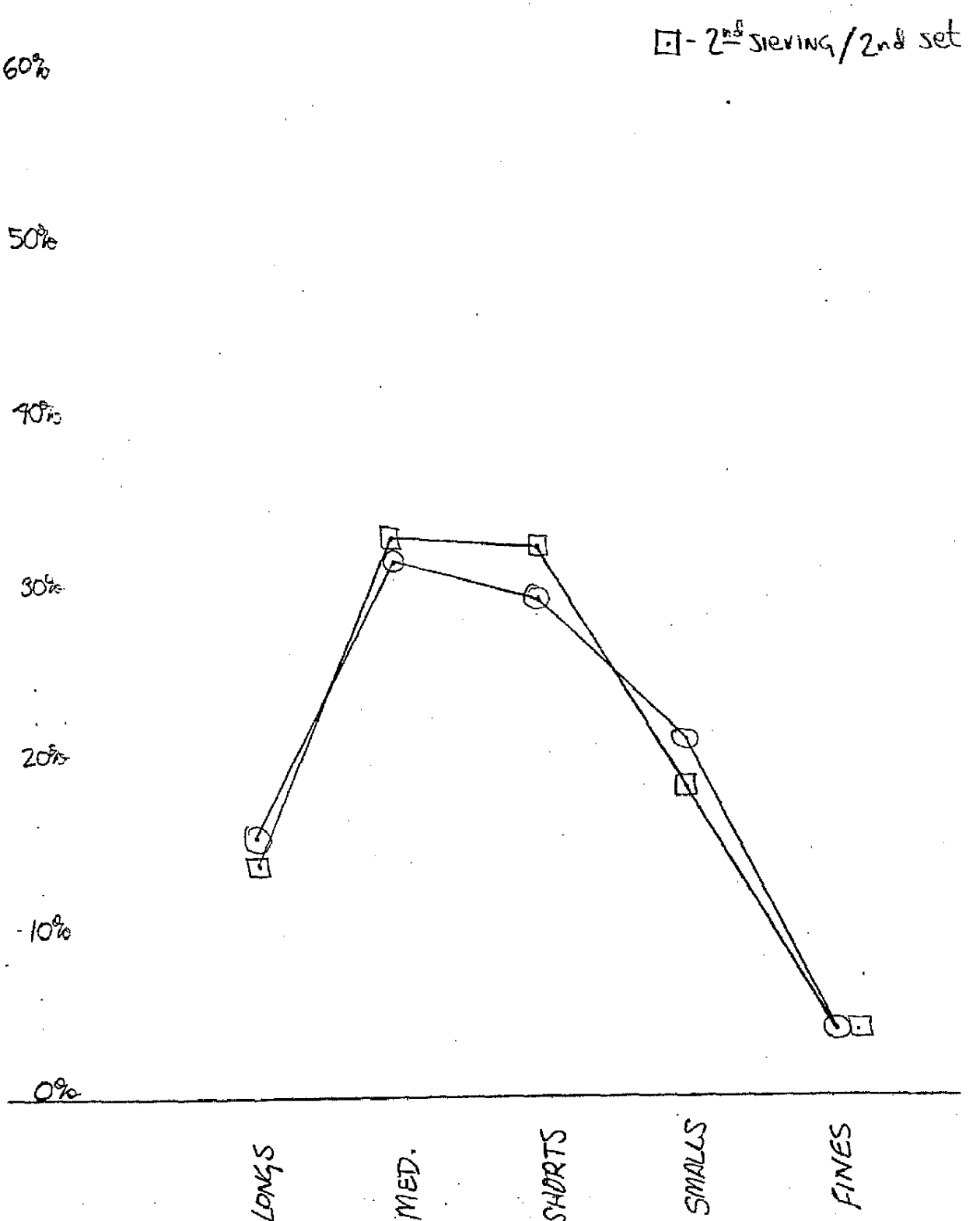
PM3000983900

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

COMPARISON TEST
MKS - FB/150 g
6, 12, 18, 35

⊙ - 1st SIEVING / 1st set

⊡ - 2nd SIEVING / 2nd set



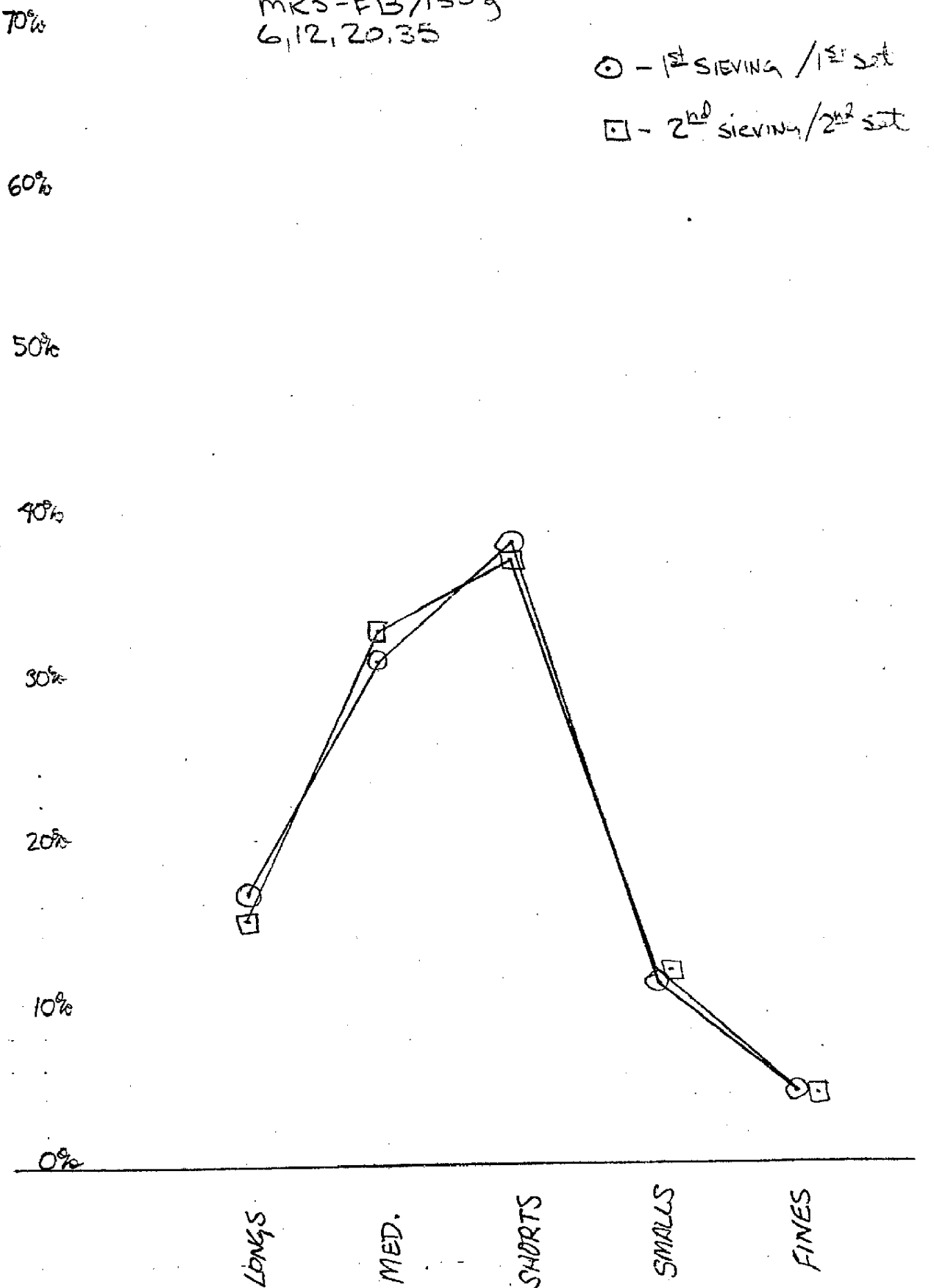
PM3000983901

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

COMPARISON TEST
MKS-FB/150 g
6, 12, 20, 35

⊙ - 1st SIEVING / 1st SET

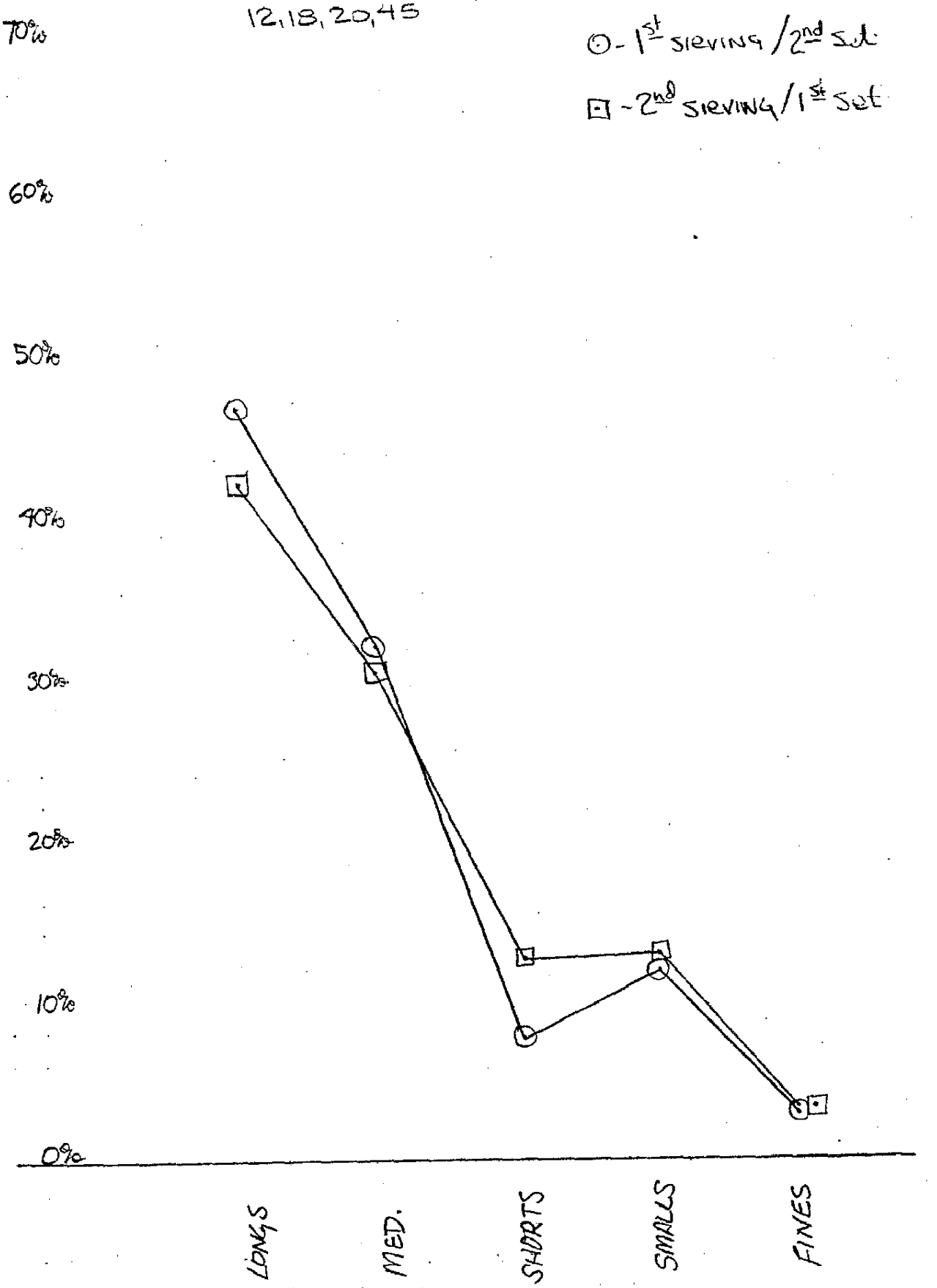
⊡ - 2nd SIEVING / 2nd SET



PM3000983902

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

COMPARISON TEST
MKS FB - 150g
12, 18, 20, 45



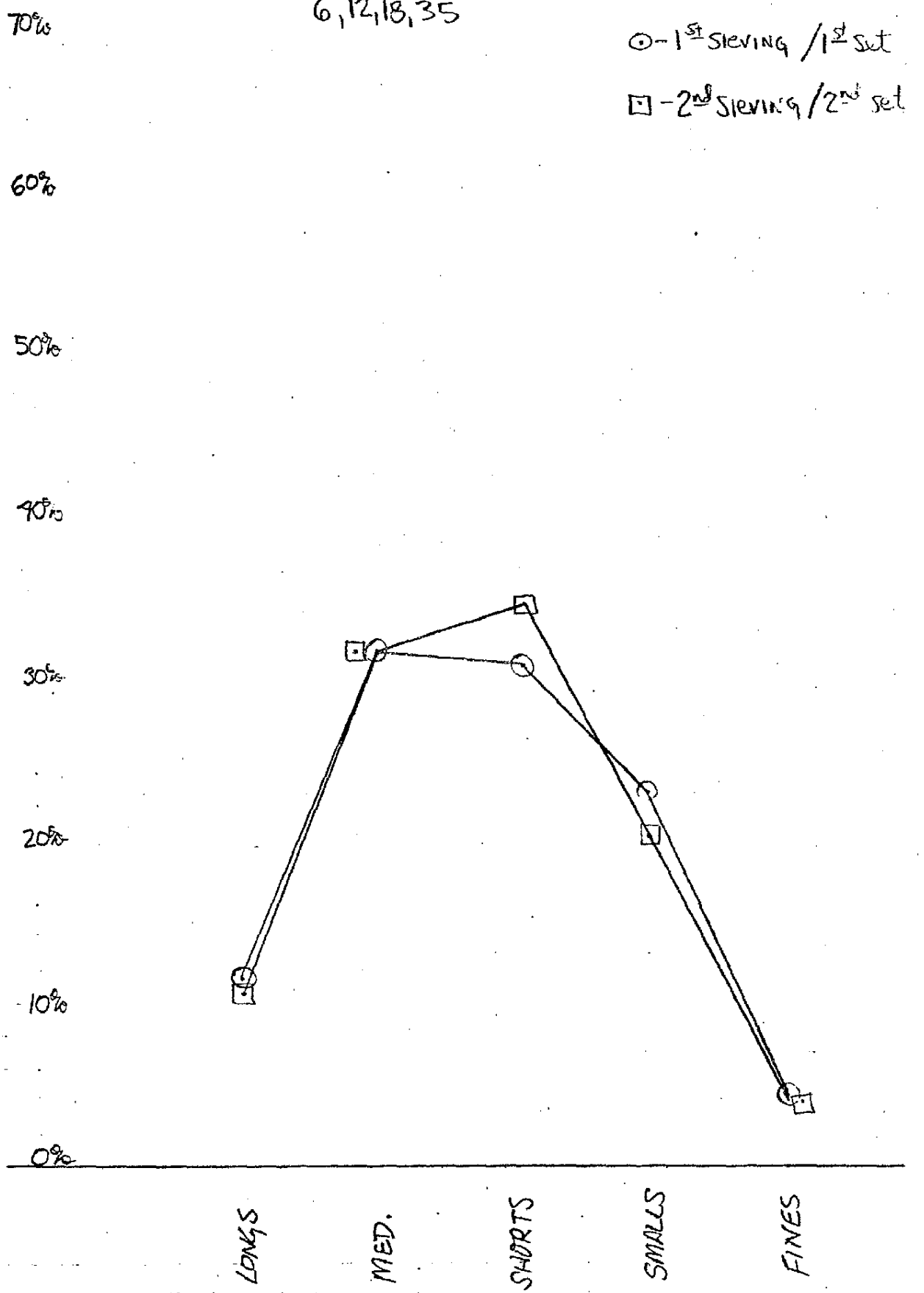
PM3000983903

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

COMPARISON TEST
MKS-FB / 100 g
6, 12, 18, 35

⊙ - 1st SIEVING / 1st SET

⊡ - 2nd SIEVING / 2nd SET



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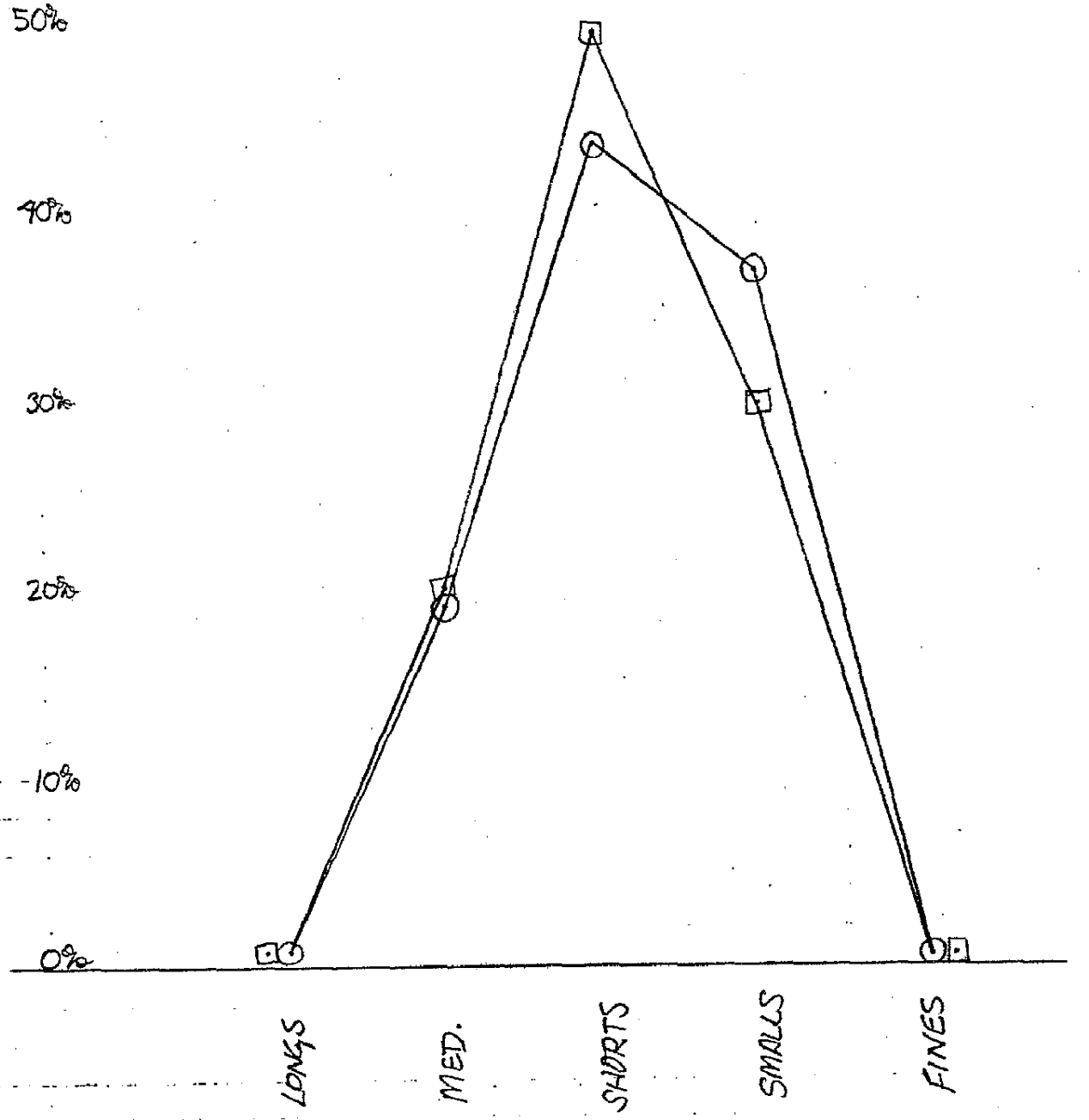
Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

COMPARISON TEST
RIPPER SHORTS - 150g
6, 12, 18, 35



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Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

APPENDIX XI

Comparison of Sets - All Fractions

MKS-FB/150g

Sieving		% Longs	% Mediums	% Shorts	% Smalls	% Fines
Degradation Test 6, 12, 18, 35	1	16.63	30.46	28.28	20.63	4.00
	2	14.52	30.57	28.91	21.88	4.11
Change in Fractions		-2.11	+0.11	+0.63	+1.25	+0.11
Comparison Test 6, 12, 18, 35	1	15.27	31.14	28.95	20.76	3.88
	2	13.70	32.49	32.02	18.06	3.74
Change in Fractions		-1.57	+1.35	+3.07	-2.70	-0.14
Difference in Sets		0.54	1.24	2.44	3.95	0.25
Degradation Test 6, 12, 20, 35	1	18.33	31.66	36.71	9.60	3.71
	2	16.08	31.91	37.82	10.36	3.83
Change in Fractions		-2.25	+0.25	+1.11	+0.76	+0.12
Comparison Test 6, 12, 20, 35	1	16.40	30.54	37.78	11.08	4.21
	2	14.84	32.47	36.90	11.77	4.02
Change in Fractions		-1.56	+1.93	-0.88	+0.69	-0.19
Difference in Sets		0.69	1.68	1.99	0.07	0.31

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Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

	Sieving	% Longs	% Mediums	% Shorts	% Smalls	% Fines
Degradation Test 12, 18, 20, 45	1	47.70	29.66	10.84	9.57	2.23
	2	45.76	29.96	11.41	10.56	2.31
Change in Fractions		-1.94	+0.30	+0.57	+0.99	+0.08
Comparison Test 12, 18, 20, 45	1	46.38	31.81	7.57	11.60	2.64
	2	41.99	30.06	12.35	12.69	2.92
Change in Fractions		-4.39	-1.75	+4.78	+1.09	+0.28
Difference in Sets		2.45	2.05	4.21	0.10	0.20

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Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

APPENDIX XII

Comparison of Sets
Combining Shorts and Smalls

Sieving		% Longs	% Mediums	% Shorts + Smalls	% Fines
Degradation Test: 6, 12, 18, 35	1	16.63	30.46	48.91	4.00
	2	14.52	30.57	50.79	4.11
Change in Fractions		-2.11	+0.11	+1.88	+0.11
Comparison Test 6, 12, 18, 35	1	15.27	31.14	49.71	3.88
	2	13.70	32.49	50.08	3.74
Change in Fractions		-1.57	+1.35	+0.37	-0.14
Difference in Sets		0.54	1.24	1.51	0.25
Degradation Test: 6, 12, 20, 35	1	18.33	31.66	46.31	3.71
	2	16.08	31.91	48.18	3.83
Change in Fractions		-2.25	+0.25	+1.87	+0.12
Comparison Test: 6, 12, 20, 35	1	16.40	30.54	48.86	4.21
	2	14.84	32.47	48.67	4.02
Change in Fractions		-1.56	+1.93	-0.19	-0.19
Difference in Sets		0.69	1.68	2.06	0.31

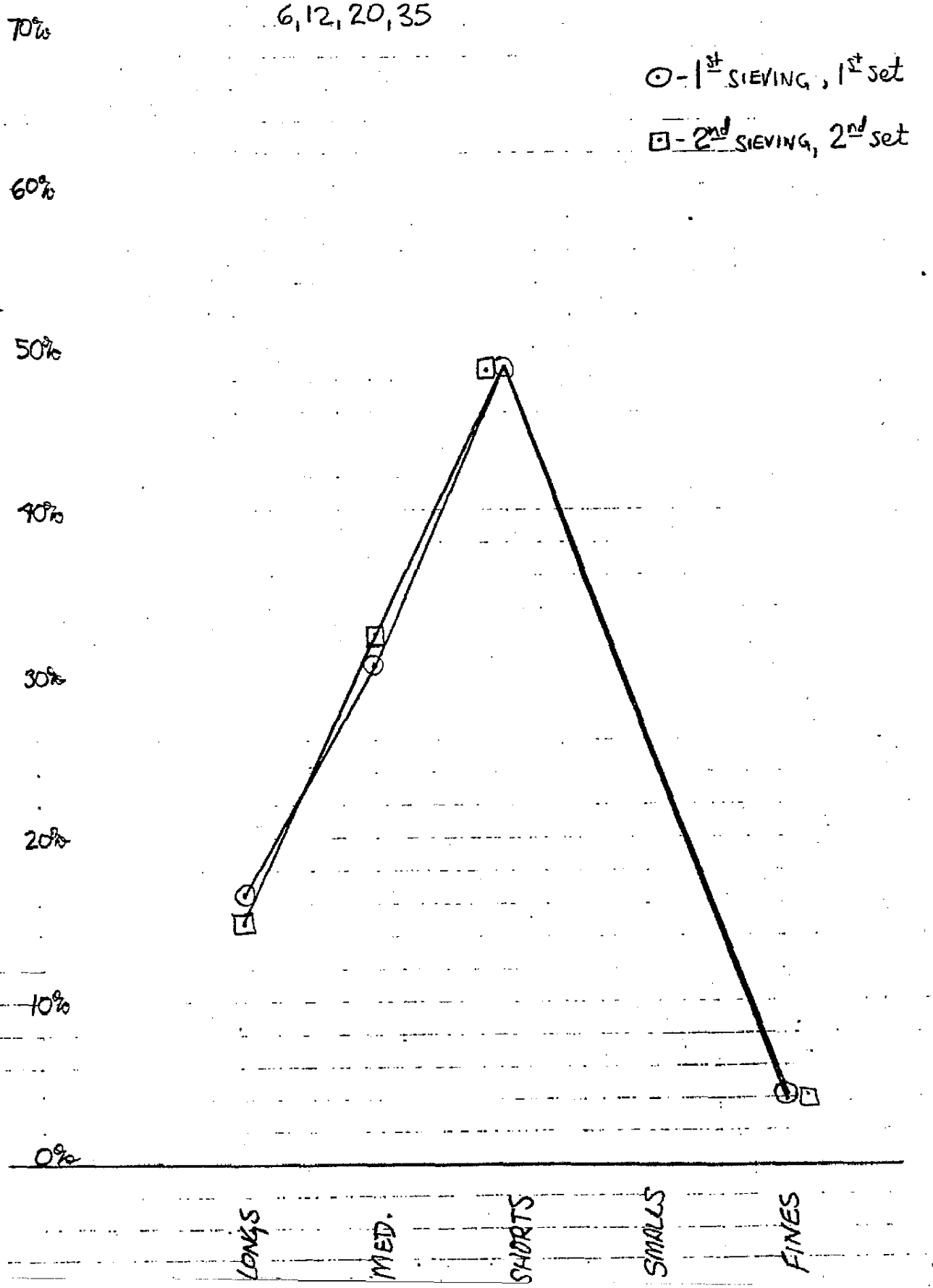
PM3000983908

Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

COMPARISON TEST
COMBINATION - SHORTS & SMALLS
6, 12, 20, 35

⊙ - 1st SIEVING, 1st set

⊡ - 2nd SIEVING, 2nd set



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Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001

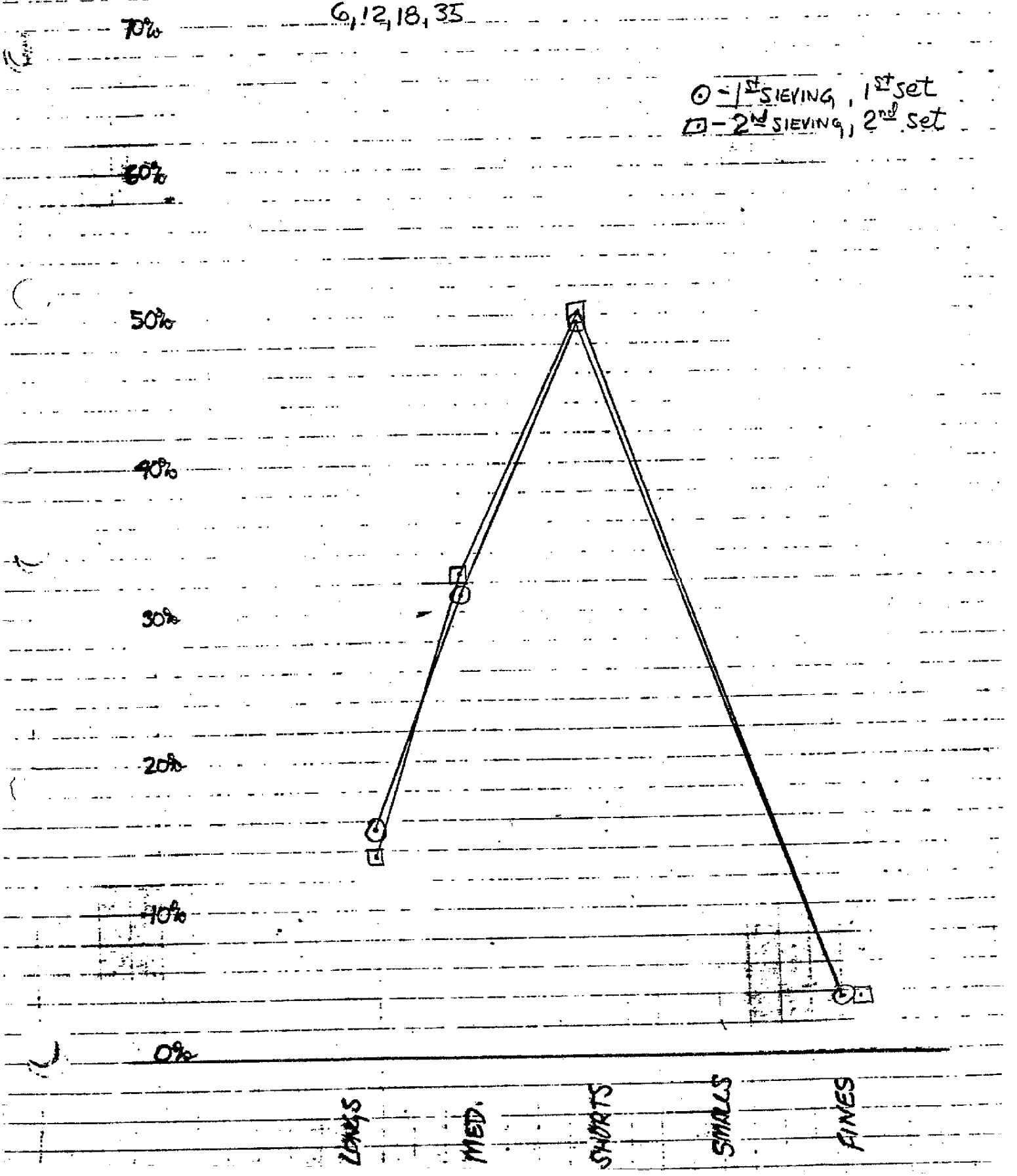
Comparison Test

Combination - Shorts & Smalls

6, 12, 18, 35

⊙ - 1st sieving, 1st set

⊡ - 2nd sieving, 2nd set



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Source: https://www.industrydocuments.ucsf.edu/docs/nkmk0001